PART III

RADIATION PROTECTION ACTIVITIES AROUND THE CERN ACCELERATORS

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1 INTRODUCTION

In 1997 the physics programme of the SPS and LEP was seriously affected by a fire in one of the surface building of the SPS; the incident caused a delay in the LEP start-up, an interruption of several weeks in the SPS fixed-target programme, and the cancellation of the lead ion run for 1997. The consequences for the experiments were, nevertheless, kept to a minimum thanks to the excellent performance of the accelerators. The neutrino experiments even accumulated a record intensity.

Experiments at the ISOLDE facility benefited from 315 shifts instead of 200 as originally scheduled, and new experiments started measuring the properties of unstable elements which play a crucial role in the stars.

LEP also reached record energy and luminosity in 1997. Measurements of synchrotron radiation in the LEP tunnel were repeated at the new energy value of 92 GeV, to comply with the demands of the INB procedure. In this context two addenda, one to the *Rapport définitif de sûreté du LEP* (the LEP Safety Report) and one to the *Règles générales d'exploitation du LEP*, were written and sent to the Direction de la Sûreté des Installations Nucléaires in Paris before Christmas.

Following the end of operation of ACOL and LEAR in December 1996, decommissioning of the Antiproton Accumulator and transformation of the Antiproton Collector into the Antiproton Decelerator started. Experiments in the South Hall were dismantled during the year and the hall will be used partly as a storage area for radioactive components and partly as a test area. Transformation of the East Hall started in September and will be completed by June 1998. Part of the hall will be used by the DIRAC experiment, the rest will be a test area for LHC experiments. In the North Experimental Area two new experiments, ALICE and NA57, were installed in the H4 beam line, following the dismantling of NA44. Dismantling work also started in the West Experimental Area, following the end of operation of the H1, H3, X1 and X3 beams at the end of 1996.

2 ACCELERATOR OPERATION SCHEDULE

The year started as usual with the long winter shutdown and major maintenance work on the accelerators and in the experimental areas. Operation began early in March, with the first beam tests in Linac 2 already on 27 February. The PS Booster started on 3 March; the first beam to the SPS was sent on 20 March. LPI started with beam on 7 April; the first e^+/e^- beams were sent to the PS on 28 April and to the SPS on 5 May. ISOLDE started on 24 April.

After a very smooth beginning in March, a serious fire in surface building BA3 on the morning of Tuesday 13 May halted the operation of the SPS/LEP complex. The fire destroyed one of the RF power supplies of the SPS and heavily polluted the entire building with acid smoke and soot. A major cleaning operation was undertaken by a specialized firm which worked round the clock for several weeks with a team of 70–100 people. Seven weeks of accelerator operation were lost and the physics programme had to be entirely rescheduled. The lead ion run in 1997 was cancelled and will be compensated by additional beam time which will be allocated in 1998. The SPS was operated with only 7 out of 8 RF transmitters from July until the end of the run.

The SPS fixed-target programme was divided into three periods. Period 1 started on 3 April and was interrupted by the fire on 13 May instead of 21 May as scheduled (with a total of 35 days of beam time for users). After the fire, the fixed-target programme was resumed officially on 4 August, but the secondary beams were actually available for physics already on 28 July. Period 2 lasted from 4 August to 1 September (28 days) and period 3 went from 3 September until 10 November (67 days), when the 1997/98 winter shutdown began.

The LEP start-up was delayed by 35 days because of the fire, but a careful rescheduling gave rise to only 25 days lost for physics over the year. The first leptons in the SPS were obtained on 11 July, the first beam in LEP circulated on 13 July, the first Z particles were detected on 19 July, and the first W^+/W^- pairs on 31 July.

3 ANNUAL DOSES AROUND THE CERN ACCELERATORS

The annual collective dose for work performed at the PS accelerator complex was 170.49 mSv (117.54 mSv for the PS ring, 31.06 mSv for the Booster, 10.63 mSv for ISOLDE, 6.87 mSv for LPI/CTF, and 4.39 mSv for the antiproton target). The annual collective doses for the PS complex are compared with those of previous years in Figs. 1 and 2.

The collective dose in the SPS complex (which includes the SPS, the target areas, the North and West Experimental Areas, the neutrino cave, and the workshops) was 471.37 mSv, of which 259.6 mSv was received during work carried out in the winter shutdown. These values are compared with those of previous years in Fig. 3.

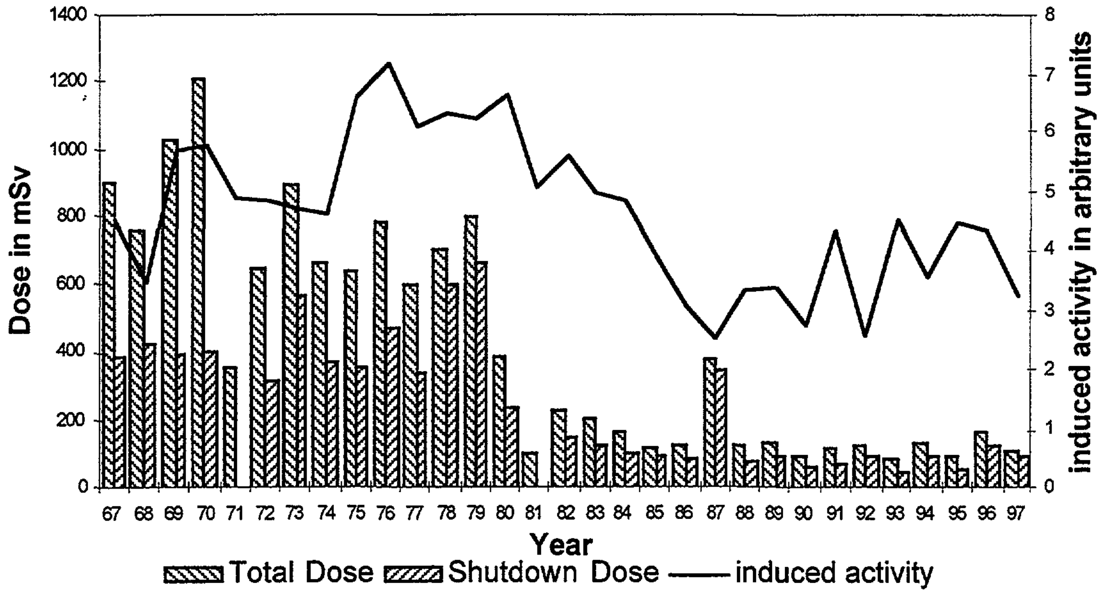

Figure 1: Collective dose for the PS ring. Histogram corresponds to dose, and the line to induced radioactivity.

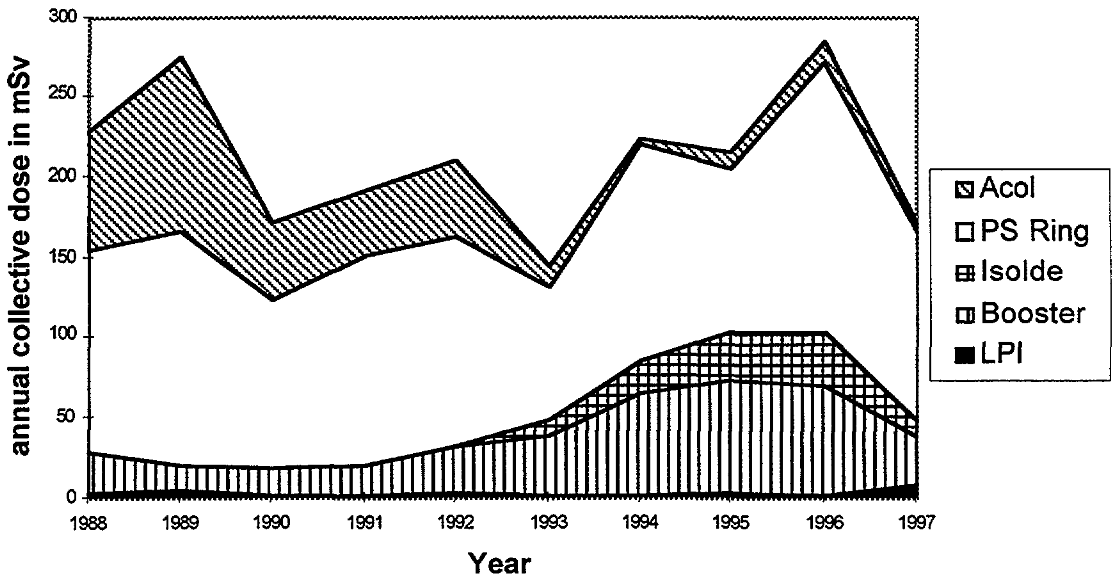

Figure 2: Evolution of the annual collective doses per area in the PS complex.

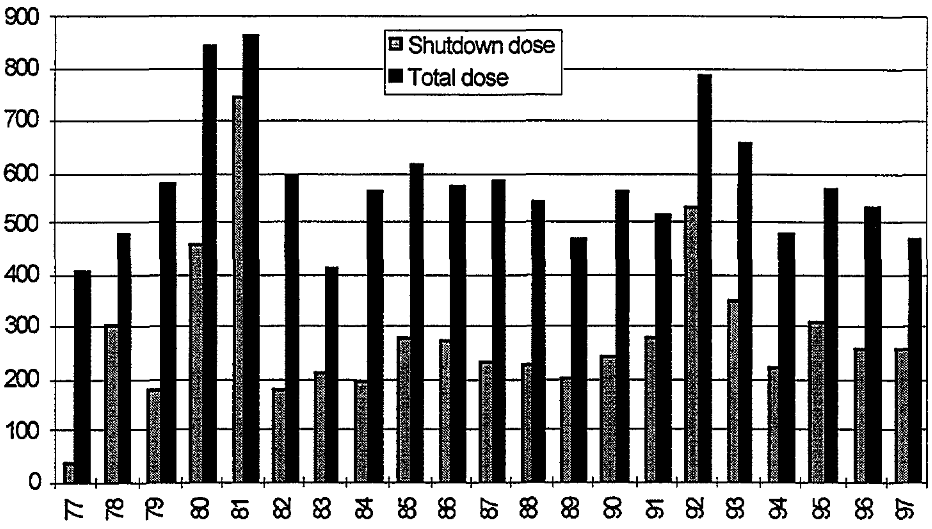

Figure 3: Collective dose for the SPS complex.

Individual doses in LEP remained negligible. Despite the further increase in beam energy, the accumulated annual doses in the experimental areas remained very low, in the 0.2–0.5 mSv range, i.e. often less than one half of the natural background as measured on the surface. In the klystron galleries the annual doses also stayed low, typically 0.4–0.5 mSv. On the other hand, annual doses increased in areas facing the access mazes UP (leading into the RA straight sections) and UJ (leading to the bending sections) at the two ends of the klystron galleries (areas with a very small occupancy factor). At the UPs the annual gamma doses range from about 3 mSv in UP63 to about 7 mSv in UP83 and UP87; neutron doses are generally below 1 mSv, with a maximum of about 4 mSv in UP63. Annual doses (gamma radiation only) at the UJs range from 1.4 mSv for UJ23 up to a maximum of 18 mSv in UJ43. The annual doses around the various access points at the surface are not discernible from background [1].

4 MACHINE SHUTDOWN

4.1 PS complex

4.1.1 PS ring

The induced activity in the PS ring at the beginning of the 1996/97 winter shutdown was slightly higher than the same period of the previous year. Only straight section 39 was fenced as a high radiation area (4 mSv/h at 40 cm distance from the accelerator). The beam loss in straight section 1 which had induced considerable activity in past years had disappeared: the dose rate in contact with the vacuum chamber was only 5 mSv/h, compared with 60 mSv/h in

1995. On the other hand, the induced activity in the Booster–PS transfer line increased to 200 μSv/h at 40 cm. Several 'hot spots' were identified in the TT2 transfer tunnel: the highest was measured on a beam current transformer (10 mSv/h in contact and 200 μSv/h at 40 cm).

The collective dose for interventions in the ring during the shutdown amounted to 85.34 mSv (30% less than the previous year) for 162 people. The average individual dose was the minimum ever recorded in a shutdown period. Checks of air and surface contamination revealed negligible values.

The 1997/98 winter shutdown for the PS complex began on 8 December, one month earlier than usual, because of important maintenance work planned in the Booster. The work carried out in the PS ring in the two weeks preceding the end of the year closure of CERN resulted in a collective dose of 10.34 mSv.

4.1.2 Booster

The induced activity in the Booster was about the same as in the previous winter shutdown, but reduced maintenance work resulted in a collective dose of only 13.78 mSv (shared amongst 44 people), i.e. a factor of 4 less compared with 1996.

The work carried out in the last two weeks of the year involved a collective dose of 13.34 mSv.

4.1.3 ISOLDE

At the beginning of the year, 30 targets (including five with alpha-activity) were sent to the ISR radioactive storage area (315 μSv received by two people). An alumina screen mounted in the beam line of the General Purpose Separator (GPS) had to be changed: it had a surface beta dose rate of 650 mSv/h and a contact gamma/beta dose rate of 30 mSv/h. An adjustable support on the front-end of the GPS also had to be replaced; the dose rate was 3.5 mSv/h in contact and 1 mSv/h at 10 cm: the intervention involved 535 μSv.

Beam perturbations in the High Resolution Separator (HRS) beam line made it necessary to dismount the beam line to undertake magnetic measurements. During this work all components in the beam line were checked for induced activity and contamination. In a few cases some contamination was detected, for example on vacuum pump connections. A collimator installed between two separators showed a surface beta dose rate of 550 mSv/h and a contact gamma/beta dose rate of 4 mSv/h.

During the decontamination of the shelves where the targets are stored 1.2 kBq of a mixture of ^{182}Ta, ^{173}Lu, ^{75}Se, ^{7}Be, etc. was recuperated. The guides for the robot cables in the pit had to be changed because of oxidation, and some contamination was detected in the smear tests. A small tantalum wire, most probably from a target, was recuperated and measured, showing a specific activity of 60 MBq/g.

The protection plates trapping the light masses in the GPS were removed mid-March following some problems. The total gamma activity was 75 MBq, whilst the surface and contact dose rates were 30 mSv/h and 1.1 mSv/h, respectively. A month later new plates were installed and at the same time the plates used to trap the heavy masses were also replaced. The gamma activity in the latter was of the order of 500 MBq; some alpha- (^{208}Po, ^{209}Po, ^{210}Po, ^{227}Ac, ^{228}Ra) and beta-activity (^{90}Sr) was also detected. The surface and contact dose rates were about 100 mSv/h and 10 mSv/h, respectively.

A water leak in the water softener in the auxiliary room behind the ISOLDE control room infiltrated the target area, depositing some 4 kg of salt which were collected in the target storage area. The measured activities were 770, 190 and 320 Bq/kg of ^{7}Be, ^{22}Na and ^{182}Ta, respectively. The area and the targets were cleaned. An analysis of the water showed an activity of 1.2 kBq/l of ^{7}Be.

The gas retention balloons were emptied three times in the course of the year, yielding a total released activity (after a decay period in the balloons) of about 2.63 GBq of equivalent tritium. The grand total released from the start of the new PSB-ISOLDE facility is about 22.3 GBq of equivalent tritium.

The collective dose received in the course of work in the target area from 1 January until the end of the shutdown period on 29 April was 7.3 mSv for 33 people.

4.1.4 LEP injectors

The main interventions in LPI were the replacement of the converter and of the downstream accelerating section. The total dose received by 9 people was 4.46 mSv.

4.1.5 Antiproton Accumulator

Some maintenance work was performed in the target area, giving a collective dose of only 680 μSv to six people. In view of the dismantling of the AA, samples were taken from the cables to be removed; their measurement by gamma-spectrometry determined that all cables were non-radioactive. A systematic check of all material leaving the AA Hall was undertaken, with radioactive material being sent to the ISR radioactive storage area.

4.2 SPS

4.2.1 SPS ring and transfer tunnels

The most important activity in the SPS during the 1996/97 winter shutdown was the replacement of cables in BA6, carried out by 15 people who received a collective dose of 59.2 mSv in the first quarter of the year (88.6 mSv for the entire work which had in fact started in December 1996). The total dose for work in LSS6 was 160.5 mSv. Other interventions worth mentioning are the maintenance work by the vacuum group in LSS1 (4.6 mSv collective dose) and maintenance work on the separators in LSS2 (10 mSv collective dose).

A new beam dump was installed in the upstream part of the TT10 tunnel which is used for the transfer of protons from the PS (along the TT2 line) to straight section LSS1 of the SPS. The new dump replaced the 20-year-old 'fail-safe' stopper TBSI installed in TT2; the dump area is complemented by a maze built in TT10 about 50 m downstream of the dump. This combination is to prevent unacceptable radiation levels on the SPS side of TT10 (some 80 m after the start of the transition between the horizontal and slowly descending floors of the tunnel), in the (accidental and unlikely) case that the beam is bent from TT2 into TT10 with the SPS being off, and people having access to the downstream end of TT10. The dump and maze combination was designed using Monte Carlo simulations. Its efficacy was confirmed by an experimental measurement in November [2].

The 1997/98 winter shutdown began on 10 November for LEP and on 14 November for the SPS. The ring survey of the SPS was carried out 30 hours after the machine was stopped. The most active areas were, as usual, sextants 1, 2 and 6 (respectively injection, extraction towards the North Experimental Area, and extraction towards the West Area and the neutrino facility). The levels of induced activity were somewhat higher than in the equivalent period of 1996. This is due to the fact that the lead ion run (which because of its low intensity induces a lower activity in the machine) was cancelled following the fire of 13 May.

As the SPS internal dump was changed only a few weeks before the end of 1997 operation (see Section 5.2.1), the induced activity in this position is now lower than in the past. The highest dose rates in the accelerator tunnel, at 1 m distance from the machine, were in the range 0.5–1 mSv/h near the injection elements, with a peak of about 5 mSv/h. Typical dose rates in the two extraction regions ranged from 0.1 to 1 mSv/h, again with a peak value of 5 mSv/h close to the electrostatic separators. The ring survey was repeated on 3 December and on that date the dose rates had decreased to the same values as in 1996. The dose rates from induced activity in sextants 1, 2 and 6 measured during the ring surveys of 14 November and 3 December are given in Figs. 4–6, and are compared with the values of the ring survey carried out the day after the fire of 13 May.

A radiation survey of the TT10 tunnel was carried out on 21 November, following a specific request from the Operation Group of SL Division. A particularly radioactive section of the transfer line was detected, with dose rates up to 400 µSv/h.

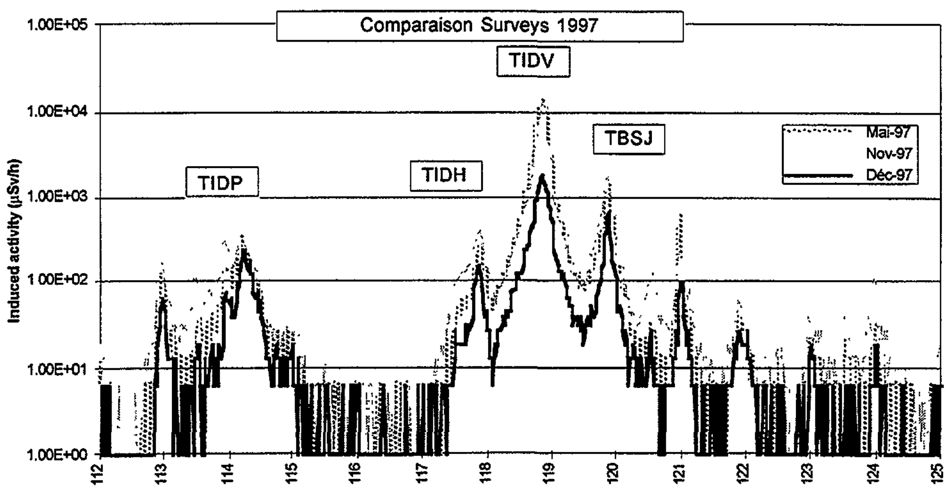

Figure 4: Induced radioactivity in sextant 1 of the SPS.

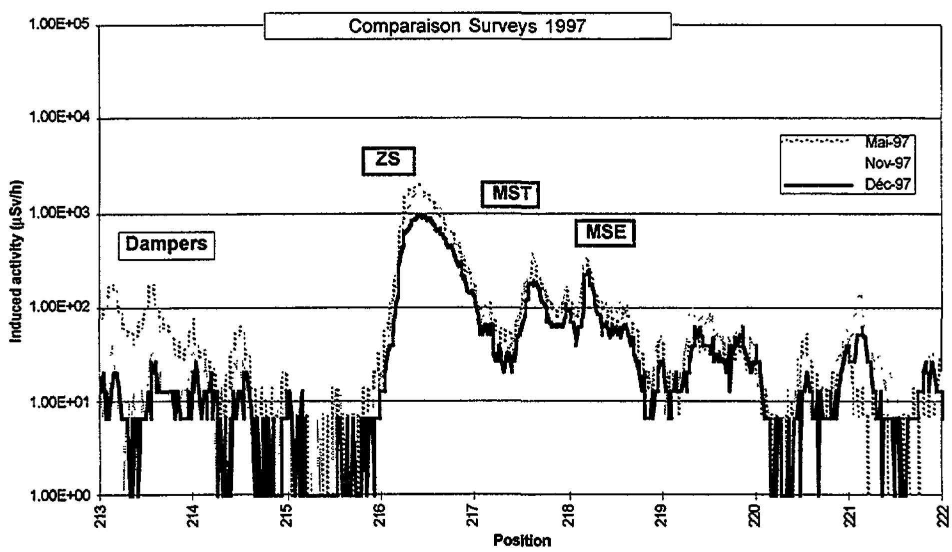

Figure 5: Induced radioactivity in sextant 2 of the SPS.

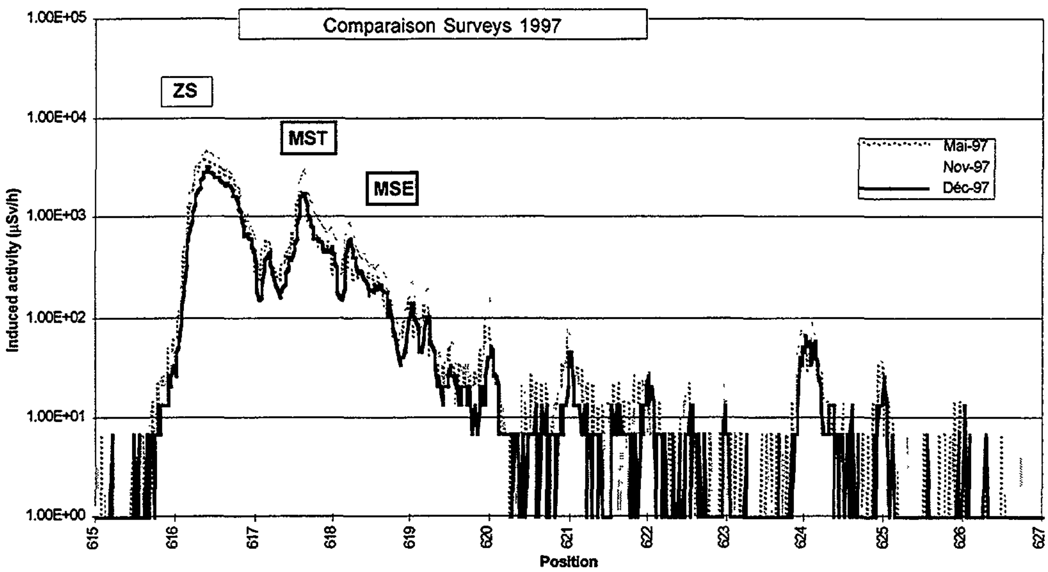

Figure 6: Induced radioactivity in sextant 6 of the SPS.

4.2.2 Neutrino

At the beginning of the shutdown, a thorough cleaning of the floor of the neutrino cave was carried out, in order to remove the rust accumulated from oxidation of metal parts and to avoid any contamination risk. The collective dose for the 1997 shutdown amounts to 35.5 mSv, to which one should add 3.8 mSv received earlier in December.

4.2.3 TCC2, TCC6, TCC8, North and West experimental areas

The radiation survey in the target area TCC2 was carried out 80 days after the end of the run. Several interventions throughout the 1996/97 winter shutdown gave rise to a cumulative dose of 30 mSv. The major work was the replacement of water connectors on several magnets, with two people receiving a total dose of 1.76 mSv; cable changing at the T2, T4 and T6 targets, where careful job planning limited the cumulative dose to 5.3 mSv shared by three people; the TAX lubrication, with 2.8 mSv shared amongst three people; and magnet alignment, with 1.82 mSv received by three surveyors.

The radiation survey in TCC6 was carried out in February, 90 days after the end of the 1996 lead ion run. The highest dose rates were measured outside the shielding of the T1 target (8.5 mSv/h), at the TAX (4 mSv/h), and at the dipoles bending the beam from TT70 (3.6 mSv/h maximum).

Only minor interventions were carried out in TCC8, with no significant dose being recorded.

In the North experimental area EHN1, all fixed radiation monitors were taken to the calibration room for their triennial calibration. The 4HC zone underwent major modifications for the set-up of the NA57 experiment, which included the installation of the large GOLIATH magnet formerly used in the West Area.

Following the decision by the Research Board to stop the H1, H3, X1 and X3 beams at the end of 1996, major dismantling work took place in the West Area, and continued throughout the year. Only the upstream part of the H3 beam now remains in operation to serve as a parent beam for the X5 and X7 beams. All components from the dismantled beam lines and experiments were checked for radioactivity, as well as about 200 iron blocks and 150 iron support beams. Only one beam had a dose rate higher that 100 μSv/h at 10 cm and most of the blocks had less than 10 μSv/h. When dismantling the H1, a total of 780 measurements were made and 15 boxes were filled with cables. Some of the cables were not radioactive and were recuperated, the rest were sent to the radioactive storage. A dozen of the fixed radiation monitors were suppressed and the positions of the rest were changed to cope with the new layout of the area. By the end of the year part of the West Hall had been emptied and, with some additional shielding still to be built between the beam lines and the rest of the hall, the area was almost ready to be handed over to the ATLAS magnet group.

4.3 LEP

A radiation survey of the injection regions was repeated at the beginning of the year, 46 days after LEP had been stopped. The maximum value of induced activity in this area had decreased during this period by a factor of 30, from 480 μSv/h to 17 μSv/h. A radiation survey was also repeated in the RF straight sections, where the initial dose rates were typically of the order of tens of μSv/h, with a maximum of 200–300 μSv/h. Here the decrease in dose rate was less pronounced with some points still detectable.

The major work during the 1996/97 winter shutdown was the installation of 16 superconducting RF modules (eight in point 2, four in point 4, and four in point 8) to raise the LEP energy from 86 GeV to 92 GeV. As last year, the labyrinths installed at the end of each of the eight RA sections on both sides of interaction points 2, 4, 6 and 8, allowed the RF group to carry out the final conditioning of the modules while maintaining access to the rest of the tunnel.

Maintenance work continued until the end of June and did not require any specific radiation protection measures. The yellow containers for radioactive waste placed at the exit of the controlled areas (the injection regions, the straight sections housing the superconducting RF cavities and the klystron galleries) were regularly checked: most of the waste collected consists of nuts and bolts, mostly non–radioactive. The entrances to all controlled areas of the LEP tunnel were equipped with self-service quartz fibre dosimeters. No significant doses were ever recorded during all the interventions thus confirming that, despite some induced activity measured around the RF cavities and in the injection region, personnel are not exposed to radiation. On the other hand, signs of radiation damage become clearly visible. In this respect, the vacuum chamber in the injection region was shielded with 2.5 cm of lead to decrease the radiation dose from synchrotron radiation which, in this part of the tunnel, is particularly high because of the double bend dipoles.

Owing to radiation damage to their electronics, the eight radiation monitors installed in the tunnel on both sides of the four experiments were replaced with PMI-type detectors with detached electronics installed outside the tunnel. These detectors also monitor radiation levels when RF conditioning is carried out during shutdown periods.

At the beginning of the 1997/98 winter shutdown a radiation survey was carried out as usual in point 1, in the RF straight sections and, in addition, in points 3 and 7, around the polarization wigglers. Only a few, well localized spots with induced radioactivity were found around the RF cavities, with a maximum around 0.8 mSv/h at 10 cm distance from the end of one cavity . This value had decreased to about 100 μSv/h after a few weeks, when a second survey was carried out just before the end of the year. Typical values are much lower, usually not exceeding 10–20 μSv/h. In the injection region, the maximum measured was 60 μSv/h, lower than in the past. In the wiggler regions the dose rate is very low, of the order of 1 μSv/h at 10 cm distance.

5 MACHINE OPERATION

5.1 PS complex

Because of the fire of 13 May, the lead ion period was suppressed and the proton run for the SPS was prolonged until 10 November. Experiments in the East Hall continued until 22 September and at ISOLDE until 29 November. The beam for ISOLDE reached a record intensity of more than 3×10^{13} protons/pulse. The LEP pre-injector complex, LPI, in addition to e^+/e^- production for LEP, was used for irradiation experiments of LHC detectors with both 500 MeV electron beams and synchrotron radiation from EPA. The performance of the accelerators of the PS complex in 1997 are summarized in Tables 1–3.

Table 1: Protons produced by the Booster in 1997 [3]

SPS	East Hall	ISOLDE	MEs	Proton Total
4.09×10^{19}	6.97×10^{17}	8.54×10^{19}	9.56×10^{18}	1.37×10^{20}

Table 2: Electrons produced by LIL in 1997 [3]

Setting-ups/MDs/ tests	e^- for LEP	$e^- \rightarrow e^+$ production for LEP	LHC irradiations	LEA irradiations
2.06×10^{19}	6.13×10^{17}	8.38×10^{19}	4.28×10^{17}	1.48×10^{18}

Table 3: Distribution of particle beams accelerated in the PS in 1997 [3]

Protons				Electrons	Positrons
SPS	MDs	East Hall	protons total		
3.43×10^{19}	1.44×10^{18}	5.18×10^{17}	3.63×10^{19}	1.01×10^{17}	9.59×10^{16}

5.1.1 PS ring

On 6 May an intervention was required in straight section 54 because of a vacuum leak in a fast beam wire scanner, and resulted in a collective dose of 350 μSv to four people. During a shutdown between 26–28 May, one dipole was replaced in straight section 30: the work, carried out in an ambient dose rate of 250–500 μSv/h, involved a total dose of 2.33 mSv to 23 people.

During a technical stop on 24 September, an intervention was required in straight section 8 to change a piston tuner of a 200 MHz RF cavity. The dose rate at the vacuum chamber was 4 mSv/h in contact and 1 mSv/h at 40 cm, representative of the ambient dose rate. The component, which was taken to a workshop to be repaired, had a contact dose rate of 500 μSv/h, but personal doses to the two workers were limited to 120 and 57 μSv.

After the stop on 24 September, unusually high levels of both induced and prompt radiation were observed at the extraction septa. The dose rate measured by the PAXS35 monitor (above extraction 16) had increased by a factor of 3. Since the beam intensity in the PS was not particularly high (2.6×10^{13} protons/pulse) this fact can only be imputed to differences in the beam steering during this period. The induced activity measured during this technical stop was higher too, compared with the same period in the previous year, by a factor of 2.6 and 1.4 in straight sections 16 and 39, respectively.

In October–November a number of TLDs were exposed in three locations, in order to obtain an estimate of the doses in these areas: Mont-Citron (there are plans to raze it to make room for a parking lot), the fence of the PS ring in the proximity of extraction 16 (where a footpath crosses the embankment of the PS ring not too far from this location), and above the TT2 tunnel behind hall 193 [where a short cut is foreseen when the Antiproton Decelerator (AD) is operational]. The maximum extrapolated values are 4 mSv/year on the Mont-Citron and at the fence of the PS ring, and 1.3 mSv/year behind hall 193.

5.1.2 Booster

Routine maintenance work carried out during the three-day shutdown at the end of May produced a collective dose of 700 μSv for seven people.

On 10 July a magnet power supply short-circuited causing a fire which required the intervention of 15 people in an ambient dose rate of 50 μSv/h. Gamma spectrometry measurements showed no trace of radioactivity in the soot and ashes, only traces of ^{22}Na, ^{24}Na, ^{122}Sb, and ^{124}Sb on the insulators, less than 1 Bq/g of ^{65}Zn and less than 0.3 Bq/g of ^{60}Co on the water tubes, and 27 Bq/g of ^{60}Co, 40 Bq/g of ^{51}Cr and less than 2 Bq/g of ^{54}Mn, ^{57}Co, ^{58}Co and ^{99}Mo on the connectors. The collective dose was 1.45 mSv. An external firm was called in to clean the traces of hydrochlorides released during the fire.

During the technical stop on 24 September, an amplifier had to be changed in the injection line Booster/PS in an ambient dose rate of 1 mSv/h; the individual dose received by the two people who carried out the work was 100 μSv.

On 20 November the accelerator was stopped to search for a water leak in the cooling circuit of one of the septa. This search involved a cumulative dose of 700 μSv to five people. In the ALARA (as low as reasonably achievable) spirit the repair was postponed to the winter shutdown, and the Booster ran for the last 10 days of operation with only rings 2 and 3.

5.1.3 ISOLDE

At the beginning of May an intervention was needed on the demineralized water circuit; although the ambient dose rate was between 1.5 and 4 mSv/h individual doses were kept below 100 μSv.

On 15 July an incident occurred when a robot hit a Nb target mounted on the front-end of the General Purpose Separator (GPS). Three people had to intervene, receiving a collective dose of 990 μSv. The incident resulted in the displacement of the front-end from its rails, the misalignment of the target, and a water leak, which rendered the target unusable. The dose rates measured during the intervention were 2.5 mSv/h ambient, 25 mSv/h 40 cm from the target support, and from 5 to 10 mSv/h at the door of the Faraday cage. On 17 July the front-end was put back onto its rails and the Nb target was dismounted. A measurement of the total contamination by gamma spectrometry of the gloves and overshoes used by the people who carried out the work showed 25 kBq of ^{7}Be, 30 Bq of ^{22}Na and 100 Bq of ^{24}Na. The total dose received was 370 μSv.

On 18 July radiation measurements were carried out in front of the door of the HV room, during a run with a Nb target at the High Resolution Separator (HRS), bombarded by 1.6×10^{14} protons per supercycle. The purpose of the measurements was to verify the effectiveness of the shielding in front of the door, which was foreseen to be removed in view of the future installation of the REX experiment. The measurements showed that a shield is necessary, but that its thickness can be reduced.

In September a second incident with a robot occurred. The robot became stuck whilst taking a Sn target from storage. Two people intervened in an ambient dose rate of 5 to 50 mSv/h, receiving a total dose of 750 μSv.

In November, an inspection of the ventilation system confirmed an anomaly in the measurement of the ventilation rate made by the ST Division which led to a 25% underestimate of the gas releases. The effectiveness of the absolute filters was experimentally determined to be 85% for the aerosols to less than 30% for chlorine. During target changing, only U and Th targets release measurable amounts of radionuclides: ^{220}Rn and ^{222}Rn amongst the alpha emitters, several iodine isotopes, as well as ^{83}Br.

On 22 November, during a production run of isotope masses 202 to 210, a beam sent into the experimental hall produced some hot spots of a few mSv/h in the vacuum chamber, mainly due to short-lived radionuclides.

In December, the floor at the entrance of the target area was remade; the specific activity measured in the old surface layer was 100 Bq/g, 80% caused by ^{51}Cr.

5.1.4 East Hall

Systematic radiation checks of iron blocks (a total of about 400 t) were undertaken. They will be used as shielding for the DIRAC experiment. Experiments require that the gamma fluence rate remains below 500 photons cm^{-2} s^{-1}: a calculation with the Microshield code showed that the corresponding maximum dose rate at 10 cm from the blocks is 10 μSv/h.

Dismantling of the East Hall started soon after the end of the run on 22 September, for the installation of the DIRAC experiment. Radiation checks were carried out on all material coming out of building 157 before it was sent to the radioactive storage. The contact dose rate on the various pieces was generally below 5 μSv/h, except in one case when it was 50 μSv/h.

5.1.5 LEP injectors and CLIC Test Facility (CTF)

Irradiation studies using synchrotron radiation in EPA and irradiation of optical fibres by electrons in LEA (the irradiation facility in LIL) continued; the set-up of the PS and SPS for transfer into LEP started at the end of April.

The upgraded CLIC Test Facility (CTF2) also started at the end of April, with a 450 nC beam accelerated to 45 MeV/c. The radiation monitoring system was improved with the installation of four detectors for checking induced activity, and one detector for the control of material leaving the area. Quartz fibre dosimeters on a self-service basis were made available at the entrance to the zone. A first series of measurements showed that when the beam is transported down the spectrometer beam line the dose rate in front of door 611 reaches 15 μSv/h, i.e. twice the limit (under transient conditions) for a supervised area. The measurements were repeated during an MD on 3 October and by shielding the door with 25 mm polyethylene the dose rate on the route Pauli decreases by at least a factor of 4.

On 11 July a copper bar was irradiated in the LEA area. The radioactive decay was monitored by an Ar-filled detector. The dose rate was 120 mSv/h in contact and 70 μSv/h at 1.5 m distance, one hour after the end of the irradiation. Three days later the dose rate at 1.5 m had decreased to 1.4 μSv/h. A determination of the total activity in the copper bar by gamma spectrometry showed mainly ^{64}Cu (4.8 × 10^7 Bq), with the addition of ^{44}Sc (10^5 Bq), ^{47}Sc (1.5 × 10^4 Bq), ^{48}V (2 × 10^5 Bq), ^{52}Mn (7.6 × 10^5 Bq), ^{54}Mn (7 × 10^4 Bq), ^{59}Fe (10^5 Bq), ^{55}Co (4.9 × 10^4 Bq), ^{56}Co (2.4 × 10^5 Bq), ^{57}Co (3.1 × 10^4 Bq), ^{58}Co (1.7 × 10^6 Bq), ^{60}Co (6.2 × 10^4 Bq) and ^{57}Ni (1.5 × 10^5 Bq). As the measurement was carried out three days after the end of exposure, ^{61}Cu (T1/2 = 3.33 h) had already disappeared. This was a test in view of the irradiation of a calorimeter (made up of copper and optical fibres), which took place in LEA on 16 August. The dose rate measured in contact with the calorimeter soon after the beam was stopped was 75 mSv/h. When it was removed two days later, the dose rate was still 3 mSv/h in contact and 75 μSv/h at 40 cm. No significant doses were received by the personnel.

5.1.6 Antiproton Accumulator

The dismantling of the AA and of the experimental areas of the South Hall continued. Several checks for radioactivity were carried out, usually with negative results.

On 8 July access to the AA target area was required to measure the target itself. The dose rate at 20 cm distance from the target was 40 mSv/h and the person received 200 μSv.

On 24 September the magnetic horn (stored at the bottom of the target area since it was removed on 17 October 1996) was taken to building 232 to be repaired. The dose rate was 90 mSv/h in contact, 7 mSv/h at 20 cm and 3 mSv/h at 40 cm. The work involved changing the fixation screws which, showing a contact dose rate of 60 mSv/h, were immediately sent to the radioactive storage. The collective dose received by four people was 625 μSv.

Old radioactive material stored in the shielded area of building 232 was removed, placed in an ANDRA container, and sent to the radioactive storage area of the ISR. The 'hottest' piece was a stripline (5 mSv/h in contact), the dose rate outside the container being 100 μSv/h. The place which became available was immediately used to store a 20 mm lithium lens which had been parked in the target area since it had been dismounted on 13 April 1995: the lens still had a dose rate of 100 mSv/h in contact, 10 mSv/h at 40 cm and 6 mSv/h at 1 m. The collective dose was 650 μSv shared by four people.

On 4 and 5 November maintenance work on the mobile shielding of the target area involved a collective dose of 1.4 mSv to five people.

5.1.7 Linac 3

Power tests were carried out on acceleration tank no. 2 on 19 November and on 1 December, reaching a maximum power of 1.35 MW. The maximum dose rate measured during these tests was 6.4 mSv/h at 80 cm distance, and several hundred mSv/h in contact. An X-ray absorption measurement showed an attenuation factor of 10 for a 9 mm lead thickness. The persons in charge were reminded that high power tests must be conducted in strict observation of the rules given in the Radiation Safety Manual.

5.2 SPS

Owing to the excellent performance of the SPS almost all targets received the same integrated number of protons as in the previous year, despite the fire on 13 May. A particular effort was made to provide the neutrino target T9 with the required intensity. The integrated number of protons on the various targets is summarized in Table 4.

Table 4: Beam intensity on SPS targets in 1997 [4]. The beam time is the time achieved for physics (approximately 80% of the scheduled time)

Period	Beam time (h)	Total number of protons on target					
		T1	T2	T4	T6	T9	Total
1	673	2.88×10^{17}	3.87×10^{17}	4.47×10^{17}	2.37×10^{17}	3.92×10^{18}	5.28×10^{18}
2	683	1.99×10^{17}	2.24×10^{17}	3.96×10^{17}	1.45×10^{17}	4.36×10^{18}	5.32×10^{18}
3	1211	5.43×10^{17}	5.30×10^{17}	1.01×10^{18}	6.13×10^{17}	8.33×10^{18}	1.10×10^{19}
Total	**2567**	1.03×10^{18}	1.14×10^{18}	1.85×10^{18}	9.95×10^{17}	1.66×10^{19}	2.16×10^{19}

5.2.1 SPS ring

The fire in building BA3 had no radiological consequences. As expected, smear tests taken in the building showed no trace of radioactivity. A radiation survey of the SPS was carried out the day after the fire, in view of possible interventions to be carried out inside the machine tunnel during the stop. The only relevant maintenance work was made on a separator and cost a collective dose of 1.5 mSv.

The most important intervention in the second half of the year, following the restart of the SPS on 26 July, was the replacement of the internal beam dump TIDV in LSS1 due to a vacuum leak which occurred on 17 October. The work was carried out in an ambient dose rate of 4–5 mSv/h, with a maximum of 17 mSv/h measured in contact. The search for the leak and the first attempts to repair the dump cost a total dose of 5 mSv shared by five people. The dump replacement was subsequently carried out by 20 people who received a cumulative dose of 8.83 mSv with a maximum of 1.2 mSv. For comparison, the same operation in 1988 (the last time the TIDV was changed) involved 26 people for a total dose of 10.97 mSv. A measurement of the cooling water gave a specific activity of 1.5×10^5 Bq/l mainly due to ^{7}Be, ^{22}Na, ^{54}Mn and ^{58}Co.

In LSS2, the replacement of a dipole resulted in a collective dose of 3.8 mSv, whilst an intervention on an electrostatic separator, carried out in an ambient dose rate of 400 μSv/h, involved a collective dose of 800 μSv. Several interventions required in LSS6 gave 8.8 mSv in total.

5.2.2 TCC2, TCC6, TCC8, North and West experimental areas

No particular work was carried out in the target areas; some doses were received in the course of a few interventions in TCC2, with a total of 3.5 mSv.

The X5 beam in the West Area was upgraded to 250 GeV/*c*. The efficiency of the XTDX dump between zones X5A and X5B was checked by several measurements at the beginning of operation. With a beam intensity of 10^6 particles/pulse the dose rate in the X5B area stays below 25 μSv/h.

In the EHN1 hall (North Area) assistance was given during the installation of two 370 MBq ^{60}Co sources in the ATLAS H8B area. The sources were installed in two shielded assemblies, both equipped with a fail-safe pneumatic-driven shutter. The two irradiators were interlocked with the access doors to the zone, and stand-alone radiation monitors (type Minialarm) were also installed as an additional safety measure.

The systematic radiation checks of the standard iron blocks used in the experimental areas, which were started last year, continued. About 300 blocks of different sizes were measured in EHN1 and marked according to their induced activity, in accordance with the classification given in last year's Annual Report.

Some difficulties were experienced with the transmission of alarms from the radiation monitors in the North Area to the alarm display in the control room, which took several weeks to resolve. However, safety was always assured, as local warnings were operational as well as the interlock action of the monitors to the beam in case an alarm threshold was exceeded.

The practice of wearing film badges in the North and West Experimental Areas has improved with respect to the previous year.

5.2.3 Gamma Irradiation Facility (GIF)

A Gamma Irradiation Facility (GIF) was set up downstream of the final dump of the X5 beam in the West Area [5]. This zone has been equipped with a 740 GBq ^{137}Cs source (dose rate of about 60 mSv/h at 1 m) used to test the large detectors (with dimensions up to 6 m × 3 m) developed for future experiments at the LHC. The detectors can be irradiated at the same time with a low muon flux (10^4 muons per SPS pulse) from the X5 beam to measure the effect of the photon background (which reproduces the background expected during operation of the LHC) on the detector efficiency and resolution. It is possible to vary the photon flux in a controlled way with a set of mobile lead filters.

The irradiation area is surrounded by concrete walls (8.4 m high and 80 cm thick) and covered by a grid roof. Access is via a standard PPE door, with a standard PPX door as an emergency exit. The safety aspects of the GIF are mainly dictated by the operation of the source, the muon flux being too weak to pose any radiation hazard. A search procedure of the area is required before the zone can be locked; the same (and unique) key which gives access to the zone must be inserted into the console controlling operation of the source, in such a way that the source can leave its shielded position only if the area is cleared and locked up. The operation of the source is interlocked to the operation of the beam line, as particles other than muons (e.g. electrons) can be transported in the X5 beam. Radiation monitors, movement detectors, fire and gas detectors complete the safety system.

With the source in its shielded position, the dose rate outside the source assembly is negligible. During operation, the maximum dose rate outside the zone is about 10 μSv/h measured at the PPX access door.

5.2.4 Neutrino

An intervention because of a water leak involved a cumulative dose of 2.7 mSv to five people. The ambient dose rate in front of the T9 target was about 20 mSv/h. Measurements of water samples taken from the closed cooling circuit of the magnetic horn and of the reflector showed a specific activity of 7.5×10^5 Bq/l and 1.7×10^6 Bq/l, respectively.

5.3 LEP

LEP was mostly run at 91.5 GeV, with some minor data-taking at other energies (Table 5). The energy was increased to 92 GeV at the end of the year.

Table 5: Summary of LEP operation in 1997 [4]

Energy (GeV)	45	65	68	90.5	91	91.5	92
Integrated luminosity (pb^{-1})	2.3	3.6	3.7	0.18	2.8	58.7	2.1

The measurements of synchrotron radiation in the LEP tunnel were repeated both at 91.5 GeV and at 92 GeV. As in the past, the measurements were made at point 4 in the RF straight section, in the bending section, in the labyrinth separating the two parts of the tunnel, at both sides and inside the waveguide ducts connecting the LEP tunnel with the klystron galleries, and in the access maze UJ43. The present results [6] are in line with the calculations and with the results of measurements made at lower energies [7–9].

Following a vacuum leak on the transition cone of one of the separators installed in point 7, it was found that this component was probably damaged by synchrotron radiation emitted by the polarization wigglers; the damaged part was slightly radioactive (70 μSv/h at 10 cm).

A systematic survey at the exit of the waveguide ducts in the eight klystron galleries, made during coasting at 91.5 GeV, showed that the dose rate is very low everywhere except at the exit of the last duct, at the very bottom of each gallery (i.e. close to the bending section). The highest values were about 600 μSv/h, localized on the duct axis about 2 m from the floor, measured at points 2 and 6. It was found that this is due to diffused radiation from a very localized source, i.e. synchrotron radiation propagating from the arc through the vacuum chamber hits the transition cone of a 'pretzel' separator which is exactly in front of the duct. Measurements with alanine dosimeters at four transition cones (in points 2 and 4) showed an integrated dose in the range 10^5–10^6 Gy/Ah; on the other hand, no induced activity was measured, which indicates that the radiation is of low energy. The 'pretzel' separators are not in use anymore, and will be dismounted during the 1997/98 winter shutdown.

A study of the specific activity induced in materials constituting the various LEP components (stainless steel, aluminium, lead, copper, and the iron/concrete combination of the dipoles) was started by exposing some reference samples on the dumps at point 5 during the entire period of LEP operation (July to November). This investigation will continue next year in the framework of estimating the amount of activity produced in LEP.

6 OTHER AREAS AND ACTIVITIES

Tests and conditioning of the superconducting RF cavities for LEP continued in building SM18: the dose rate in the occupied areas always stayed below 7.5 μSv/h. The test area in SM18 is being modified with one of the three test bunkers being dismantled and shielding added to the other two. The test area will then be ready to run high power tests (using klystrons instead of RF amplifiers as done at present) at the beginning of 1998.

In building 180 (the West Experimental Area) the conditioning of the RF cavities did not produce any significant dose rate outside the 'string' test area. Measurements of induced activity on the vacuum valves and copper absorbers placed on the axis at the cavity ends were regularly carried out before each cavity was dismounted and taken to LEP. With the help of two students from INSTN in Cadarache and from the University of Grenoble, a study was made on the production of gamma/neutron radiation by the cavities [10].

In building SD18, on top of the PM18 shaft 'looking at' the injection region of the LEP tunnel, a mobile shield (5 cm lead) was installed on the small duct that penetrates the 40 cm concrete floor, used by the surveyors. A few weak points in between some of the concrete blocks will also be shielded by lead early in 1998.

Most of the people carrying out regular work in the PS and in the SPS were equipped with electronic pocket dosimeters (MGP type DMC100), first introduced in 1996, to complement the film badge. In spite of some RF interference problems (discussed in the next chapter), these devices have proven extremely useful. People became very quickly accustomed to them and their distribution will be extended in the future.

Several VIP visits took place in the course of the year in radiation areas where visits are normally excluded (and in any case always prohibited for 'tourists'). These visits were necessary in order to inspect some parts of the SPS tunnel where civil engineering work will be carried out for the LHC project. Strict rules are observed when allowing people who are not radiation workers into high radiation areas (such as target areas). A maximum of seven visitors are accompanied by two authorized CERN specialists and their individual dose is limited to 100 μSv.

A soil-charging test carried out on the surface at LEP point 5 required a large amount of iron blocks that had to be checked for radioactivity before being transferred from either the West or the North Experimental Areas. Only non-radioactive or slightly radioactive (< 10 μSv/h at 10 cm) blocks were used. The test was foreseen to charge a surface of 4×4 m^2 with 1700 t, but was stopped at 1200 t with a soil-sinking of 14 cm.

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SURVEY REPORTS PS SECTION

No.	Date	TITLE
97–01	06.01	Ring survey PS
97–02	06.01	Ring survey Booster
97–03	14.01	Résultats des contrôles de contamination surfaciques pour 4e trimestre 1996
97–04	29.01	Bilan des doses personnelles pour le complexe PS en 1996
97–05	10.02	Doses et contaminations mesurées à ISOLDE en 1996
97–06	16.04	Résultats des contrôles de contamination surfaciques pour le 1er trimestre 1997
97–07	19.02	Analyses de câbles du AA avant démantèlement
97–08	27.03	Cartographie à l'extrémité de l'ancienne ligne de faisceau primaire de la zone Est
97–09	01.04	Exposition de dosimètres intégrateurs TLD autour des accélérateurs du complexe PS en 1996
97–10	02.04	Retrait des ailettes dans l'aimant séparateur GPS
97–11	08.04	Grand arrêt annuel du complexe PS en 1997
97–12	23.05	Utilisation de blocs de fer pour les blindages de l'expérience DIRAC
97–13	26.05	Ring survey PS

No.	Date	TITLE
97–14	26.05	Ring survey Booster
97–15	25.06	Mesures de radiations à la porte d'accès du CTF2
97–16	17.07	Contamination des équipements "vide" pour les radio-isotopes produits à ISOLDE.
97–17	08.08	Mesure du débit de dose devant la porte du local HT d'ISOLDE
97–18	16.09	Résultats des contrôles de contamination surfaciques pour le 2e trimestre 97
97–19	07.10	Compte rendu des niveaux de radiations dans le PS pour la seconde quinzaine de septembre 1997
97–20	14.10	Mesures de radiation autour de la ports d'accès.
97–21	01.12	Ring survey PS
97–22	02.12	Ring survey Booster
97–23	17.12	Contrôle du niveau de radiations en divers points du complexe PS au cours du dernier cycle de fonctionnement

SURVEY REPORTS SITE SECTION

No.	Date	TITLE
97–01	26.02	Doses gamma autour du bâtiment 300 (ancien synchrocyclotron)
97–02	22.04	Contrôle de l'installation d'irradiation de circuits électroniques
97–03	01.07	Réhabilitation de la zone du parking (près des bât. 180/183 - Site Meyrin)
97–04	01.11	Traitement des châssis supports d'aimants (ISR)
97–05	01.11	Réutilisation des anciennes culasses d'aimants ISR dans le cadre du projet LHC

SURVEY REPORTS SPS/LEP SECTION

No.	Date	TITLE
97–01	13.02	Mesures d'activité induite dans les zones d'injection et radiofréquences du LEP
97–02	24.02	Comparaison des mesures de rayonnement dans le puits PM18 à 45, 68 et 86 GeV
97–03	10.03	Activité induite dans les zones d'injection et d'extraction du SPS
97–04	10.03	Activité induite dans TT60 et TCC6
97–05	17.03	Echange de raccords Walther dans TCC2
97–06	04.40	Travaux effectués au SPS pendant l'arrêt machine du 2.12.96 au 7.3.97.
97–07	02.04	Travaux dans la Zone Nord de janvier à mars 97
97–08	09.04	Démontage de la ligne du faisceau H1, du TCC6 au TT5
97–09	05.05	Mesures autour du XTDX sur le faisceau X5

No.	Date	TITLE
97–10	07.05	Mesures autour de la zone GIF
97–11	16.05	Mesures autour d'un générateur de rayons X dans le bâtiment 7
97–12	16.06	Mesures autour d'un générateur de rayons X utilisé pour des radiographies de soufflets de chambres à vide.
97–13	15.08	Installation de sources de ^{60}Co dans la zone H8B de EHN1. Mesures du rayonnement à l'extérieur de la zone.
97–14	02.09	Doses intégrées sur la fibre optique du LEP en 1996.
97–15	04.09	Intervention au LSS3
97–16	18.09	Mesures en tête du puits PM18
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97–18	31.10	Mesures de débits de dose aux entrées des guides d'ondes - Points 2–4–6–8
97–19	22.10	Echange du TIDV en LSS1
97–20	04.11	Installation de deux détecteurs de type mini-alarme dans la zone H8B de EHN1
97–21	11.11	Shutdown LEP, survey du 11.11.97
97–22	01.12	Mesures d'activité résiduelle, LEP-Point 7
97–23	25.11	Radiation survey en TT10
97–24	27.11	Doses intégrées dans le hall de montage du SPS du 12 décembre 1996 au 24 novembre 1997
97–25	02.12	Doses intégrées dans les BAs du SPS au niveau des stations de refroidissement
97–26	02.12	Doses intégrées en ECA 4 et ECA 5 pendant l'année 1997
97–27	03.12	Mesures d'atténuation du rayonnement au LEP et à SM18
97–28	10.12	Doses intégrées dans les zones expérimentales du LEP pendant la période de physique 1997
97–29	17.12	Objets radioactifs trouvés dans les bacs métaux lors des contrôles hebdomadaires en 1997
97–30	17.12	Mesures des doses intégrées en 1997 sur la fibre optique du LEP
97–31	18.12	Mesures des doses intégrées en 1997 au puits PX15
97–32	19.12	Contrôle des conteneurs pour déchets
97–33	08.01	Mesures des doses intégrées en 1997 dans la chicane RE42