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1. INTRODUCTION

The year 1996 was a remarkable one for the PS. The 9 accelerators of the PS complex worked like clockwork, and a number of beam intensity records were broken; the quality of the beams delivered achieved new heights; and all this with fewer and fewer staff. In August, the Division hosted what turned out to be one of the most successful ever in the long series of International Linear Accelerator Conferences, culminating in a visit by 250 of the participants to our facilities. And finally, in December, the antiproton story at CERN reached its conclusion for the time being, as the LEAR machine was closed down for physics after operating so successfully for 14 years. The AC and AA machines which collect and store the antiprotons were also closed down, so suddenly the 9 accelerators of the PS complex became 6. However, there are plans for a rebirth of low energy antiprotons next year if the AD project is accepted, when the AC machine will be modified and become the AD, or Antiproton Decelerator machine. Meanwhile, LEAR will be used next year for tests with ions in preparation for this machine to re-surface in a few years as the ion storage ring of the LHC era, where dense ion beams will be prepared before injection into the LHC accelerator chain. LEAR is dead, long live LEIR (the Low Energy Ion Ring).

2. OPERATION OF THE PS COMPLEX AND ACCELERATOR STATISTICS

The year 1996 was one of the best ever for the 9 accelerators of the PS complex, with a new record number of operating hours achieved, a low fault rate and excellent beam performance. The PS complex ran for 6829 hours of which more than 5500 hours were devoted to physics. Overall availability was of the order of 92% for the beams delivered to SPS and for the antiproton beams used by LEAR experiments. On the performance side, new intensity records were reached for the beams sent to SPS: 2.919 10^{13} protons per cycle accelerated to PS transition and for the Pb ion beam, 2.85 10^{10} charges of Pb^{82+} per cycle. Tables 1 to 4 show the performance figures for the whole complex, detailed by type of beam.

Table 1

Operational Statistics for Lepton Operation in 1996

Total number of hours scheduled for lepton operation	5327 hours
Total number of hours achieved for lepton operation	5128 hours
Hours scheduled for lepton production for SPS/LEP	3382 hours
Hours achieved for lepton production for SPS/LEP	2954 hours
Electrons supplied to SPS/LEP	0.89 x 10^{17}
Positrons supplied to SPS/LEP	0.97 x 10^{17}

Table 2

Operational Statistics for Proton Operation in 1996

Total number of hours scheduled for proton operation	6794 hours
Hours scheduled for setting-up and Machine Developments (MD's)	779 hours
Hours scheduled for proton production (SPS)	4225 hours
Hours achieved for proton production (SPS)	3896 hours
Protons produced for SPS (PSB extraction)	4.02×10^{19}
Protons for antiproton production (PSB extraction)	2.97×10^{19}
Protons for East Hall test beams (PSB extraction)	3.32×10^{17}
Hours scheduled for ISOLDE operation	2919 hours
Hours achieved for ISOLDE operation	2796 hours
Protons supplied by PSB for ISOLDE operation	5.59×10^{19}

Table 3

Operational Statistics for Antiproton Operation in 1996

Hours scheduled for AAC operation	6260 hours
Hours achieved for AAC operation	6084 hours
Total number of antiprotons produced by AAC	4.40×10^{13}
Maximum stack	0.95×10^{12}
Hours scheduled for LEAR physics operation	5450 hours
Hours achieved for LEAR physics operation	4983 hours
Hours scheduled for LEAR setting up and Machine Developments	724 hours
Hours used for setting up and machines studies	685 hours
Total number of antiproton pulses injected	4956
Number of pulses extracted for LEAR physics	4485
Total number of antiprotons injected into LEAR	2.35×10^{13}
Number of antiprotons ready for extraction from LEAR for physics	1.72×10^{13}

Table 4

Operational Statistics for Pb-ion Operation in 1996

Hours scheduled for ion production (SPS)	1282 hours
Hours achieved for ion production (SPS)	1191 hours
Pb ions for SPS (charges of Pb^{53+} at PSB extraction)	1.95×10^{16}
Pb ions for SPS (charges of Pb^{82+})	1.90×10^{16}

After the two and a half month shutdown, dedicated as usual to general equipment maintenance and to new installations or modifications in all machines, the PS Complex restarted on 4th March. As in previous years, 1996 was divided into 3 operational periods. The SPS fixed target physics programme took protons in runs 1 & 2 and Pb ions in run 3, LEP operated for runs 2 & 3, and LEAR, ISOLDE and the East Hall were supplied with beam whenever possible throughout the year.

2.1 First Operational Period (4th March - 2nd June)

The start-up was spread out over 6 weeks and, for each beam included several days at the beginning devoted to tests of the new elements of the PS control system installed in the shutdown. The first week, which should have been dedicated to the setting-up of the proton beam in Linac 2 and Booster, was seriously disturbed by a problem on a magnet power supply in the Linac 2-Booster transfer line. Due to this and to other classical problems occurring during every start-up, the beams were only available in the Booster at the end of the week. However, in spite of a general power glitch which affected the machines for more than 12 hours, the following weeks were successful for the setting-up and the control tests.

The beams were successively adjusted in order of their priorities. The 14 GeV/c beam was delivered first at low intensity for SPS setting-up. The AAC started very well with the 3.5 GeV/c test beam and rapidly switched to normal antiproton production over Easter. The week after Easter was devoted to antiproton transfers, which started with good efficiencies of around 80%. Before receiving antiprotons, LEAR took protons for its setting-up and then protons and Pb ions for machine developments. Four weeks were dedicated to these tests before the scheduled running with antiprotons after Easter. Several settings of the LEAR machine were tried for the Pb ions and numerous measurements were carried out on beam lifetime and cooling time, especially with Pb^{54+} ions. Then LEAR switched to antiproton physics at 200 MeV/c for the start of its last year of experiments. Table 5 shows how LEAR was used during the year and the typical performances obtained.

SPS took protons for physics on the Easter weekend on the first two cycles of the supercycle. The intensity of the 14 GeV/c proton beam was gradually increased and reached 2.3 10^{13} protons per pulse. In May a special proton beam was set up at 26 GeV/c on the last cycle of the PS supercycle which was used by SPS for machine developments. Whenever it was not needed by SPS, this cycle was replaced by a third production cycle for AAC, especially during nights and weekends, in order to ensure that there was always a good "stack" of antiprotons ready for LEAR.

After several weeks spent on hardware tests, lepton setting-up went well for LPI but it was more laborious in the PS due to the complexity of this operation: there were problems at low energy, with setting-up and tests of the new controls for electron and positron extraction, there were synchronisation problems, lack of timing diagnostics and faults on beam instrumentation. For all these reasons, the leptons were delivered to SPS with a delay of about one week. Due to this the lepton schedule had to be modified, and one supplementary week was given to SPS between two weeks dedicated to LPI machine studies and irradiation tests for LHC vacuum chambers.

Five weeks of the first running period were used by East Hall experiments: the first and last weeks by PS211 which received a new, fast-extracted proton beam at 3.5 GeV/c, and the other three weeks by test experiments supplied by the classical slow extraction at 24 GeV/c. ISOLDE started later than foreseen due to target problems but then worked very well, requesting high intensity proton beams from the Booster at intensities close to 3 10^{13} protons per pulse.

A total of 10 different beams were provided for the PS users during this first running period, but in spite of this operational complexity, beam availability did not suffer. There was a lengthy electricity supply cut during an incident in the MCR on 28th April when a former employee (who had sabotaged the PS a year earlier) demonstrated by occupying the control room. This event was responsible for an extra fault rate of 3% for the antiproton beams and 6% for leptons.

Table 5

Experiments supplied by LEAR in 1996

Weeks	Experiment Number	Momentum (MeV/c)	Antiprotons per second	Mean spill duration (minutes)
15 - 20	PS195	200	800 k	45
	PS197	200	10 k	45
	PS205	200	15 k	45
21 - 22	PS205	200	fast extraction	
24 - 27	PS195	200	900 k	70
	PS201	200	30 k	70
28 - 29	PS207	105	500 k	20
30 - 31	PS201	105	25 k	60
	PS197	105	25 k	60
32 - 33	PS201	105	30 k	50
	PS194	105	250 k	50
34 - 36	PS197	1050, 609, 1350	500 k/200 k	120
37 - 39	PS201	105	50 k	60
	PS209	105	50 k	60
41 - 49	PS197 & PS185	900,1800, 1525, scan 1400 & 1633.8	200 k-750 k 200 k-750 k	100 100
16-20, 24-33, 37-39, 50-51	PS196 / PS200	105	fast extraction	

2.2 Second Operational Period (6^{th} June - 29^{th} September)

The second operational period of 17 weeks was one of the longest on record, but turned out to be good for beam availability as well as for performance. A new intensity record of 2.919 10^{13} protons per pulse was accelerated to PS transition on 17^{th} August, with less than 2.5 10^{12} protons lost between Booster extraction and PS transition. The previous record to transition of 2.7 10^{13} protons per pulse dated from way back in 1993, but the losses of 3.7 10^{12} were too great then for this beam to be kept operational. The beam for SPS fixed target physics immediately benefited from this improved performance, which was obtained after numerous adjustments of the RFQ, of the transfer line to and extraction from the Booster, and of injection, low energy tuning and continuous transfer in the PS. Proton intensities were recorded consistently between 2.3 10^{13} and 2.7 10^{13} at 14 GeV/c depending on the SPS request. This excellent performance allowed the SPS to obtain 2 new records for 1996: a new peak intensity at 440 GeV of 4.63 10^{13} protons, and the highest integrated intensity delivered on targets of 2.29 10^{19} protons.

LEP operation lasted some 10 weeks, including 10 days devoted to setting-up. Some difficulties were encountered at the beginning with the fine synchronisation between PS and SPS and with instabilities of the electron beam in the PS due to the quality of the vacuum, but in general it was a successful run. After the stop of LEP physics on 19^{th} August, LPI continued for 5 weeks for machine studies and LHC irradiation tests.

This second operational period was also very good for the antiproton beams delivered to the South Hall experiments with an availability reaching 93%, good AAC-LEAR transfer efficiencies (averaging 75%) and excellent performance of the beams supplied by LEAR (Table 5). The AAC ran remarkably well without a single stack loss during the whole run, thus creating yet another new record of 112 days with an antiproton beam circulating in AA.

The ISOLDE experiments requested alternately high and low intensity proton beams, depending on their target. The high intensity started with about 2.8 10^{13} protons/pulse but this evolved, following numerous adjustments of Linac 2 and the Booster, to exceed 3.1 10^{13} protons/pulse. For the low intensity cases, the beam was of the order of 4 10^{12} protons/pulse. In parallel, the East Hall test experiments were supplied over an 11-week period by spills of 400 ms at 24 GeV/c. Experiment PS211 installed in the t7 line worked for 3 weeks and received a new fast-extracted proton beam from the PS at 3.5 GeV/c.

The major fault during the period was a leak on the septum magnet used for electron injection into PS straight section 74. After the installation of the spare magnet, a whole series of problems was encountered: firstly there was a leak on this magnet which was repaired; then one of its water cooling circuits blocked; this caused us to remove it from the PS ring for investigations in the laboratory in order not to disturb the other beams; it proved to be impossible to remove the blockage in the water circuit, so finally, after a bake out, the spare unit was reinstalled in the PS, but with only 50% of the water flow, which the experts considered could be tolerated for a limited period. Due to this, LEP lost 8 days of colliding beam physics but nevertheless used the positron beam for machine studies. All the other PS users were disturbed for about 3 days.

2.3 Third Operational Period (2nd October - 19th December)

At the beginning of October a 4-day shutdown was devoted to equipment maintenance in all machines and to the installation of the prototype 40 MHz cavity in the PS, ready for the LHC era. After setting up with protons, SPS switched to Pb ions, which were delivered on the first 4 cycles of the 19.2s supercycle. Beams of up to 2.5 10^{10} charges of Pb $^{53+}$ were routinely accelerated in the Booster. This performance, a distinct improvement over 1996, was mainly due to the better vacuum in the Booster. As a consequence, the PS complex was able to deliver more than 2.5 10^{10} charges of Pb^{82+} per cycle after the stripper device installed in the PS-SPS transfer line. A new record was obtained with 2.85 10^{10} charges of Pb^{82+} per cycle. Fig. 1 shows the complexity of a typical supercycle which contains Pb-ions, protons for the East hall, antiproton production, antiprotons for LEAR, protons for machine development studies, and electrons/positrons for LEP. Such a supercycle demonstrates very well the enormous flexibility of the PS complex.

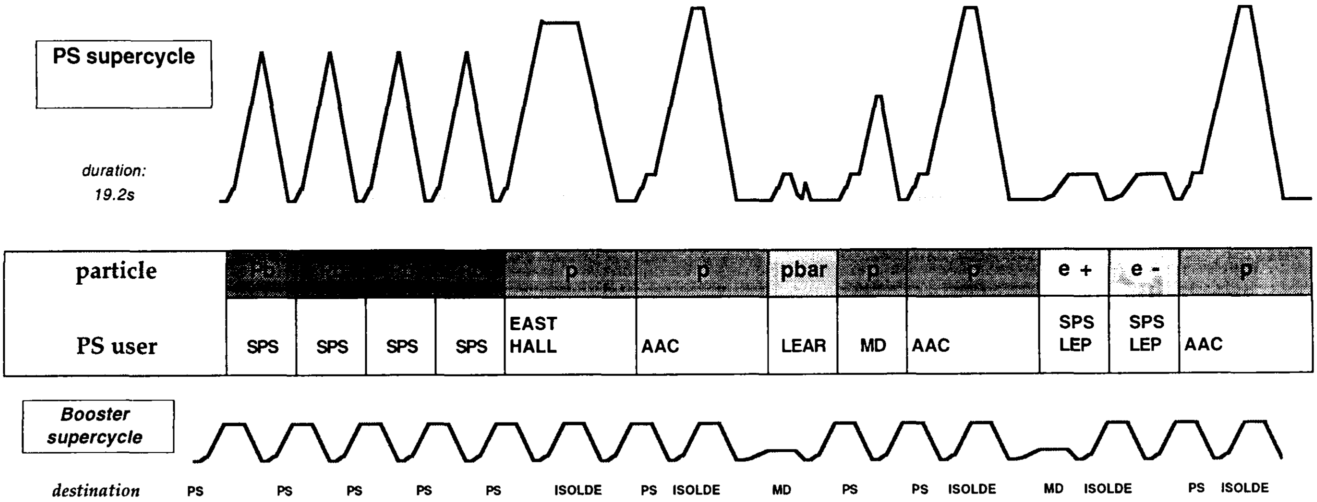

Figure 1

An Example of a PS Supercycle with many different users

Lepton operation for SPS and LEP proceeded uneventfully until the 25th November and was once again followed by machine studies on LPI and irradiation tests in the LIL experimental area (LEA). As in the second running period, ISOLDE used both low and high intensity beams, but this time the staggered beam (3 PSB rings with 1.5 10^{13} protons per pulse) was more in demand, although not in operational form until next year. The East Hall started with experiment PS211 at 3.5 GeV/c for one week and then switched to slow extraction at 24 GeV/c supplying the usual 4 beam lines.

LEAR worked for 9 weeks for Crystal-Barrel (PS197) and Hyperons (PS185) and finished its life with 2 weeks dedicated to the Trap experiment (PS196). The transfer efficiency from AAC to LEAR was rather variable (between 70 and 90%), and there were several problems with vacuum leaks, with the magnetic horn and strip line, and with the AC radiofrequency system. In addition, power cuts seriously affected all the machines of the PS complex. However, LEAR worked right up to the last moment and went out with a bang on 19th December at the official closing ceremony when highlights from its exciting 14-year career were recounted. Farewell LEAR!

3. OPERATION WITH LEPTONS

3.1 LEP Pre-injector, LPI

In 1996 LPI supplied lepton beams to the PS for LEP with an availability of more than 95 %, including stops due to power failures. In order to protect the lepton injection system of the PS against irradiation arising when particles are not requested, two pulsed power supplies were installed on the switching magnets used to direct the beam into the PS, so that either the electrons are injected, or they are dumped in a clean way. This switching, which is automatically controlled by the beam requests coming from the lepton users, is already operational on electron beams and will be available also on positron beams from 1997 onwards.

Following on from successful tests made in 1995, it was decided to produce regular lepton beams operationally using only five klystron modulators instead of the six available in LIL (LEP Injector Linac). But the experience gained during the first runs of 1996 was so satisfactory that it allowed the 500 MeV beam to be produced using only 4 modulator assemblies. In this way, the modulators run more efficiently and as few klystrons as possible are in use, which is important because they have a limited lifetime.

4. OPERATION WITH PROTONS

4.1 Linac 2

Our proton Linac continued to operate in its usual reliable manner. The major leak that perturbed its operation at the end of 1995 was repaired during the shutdown (though with some effect on the tuning margin), but this event served to demonstrate that major maintenance work is needed on the vacuum sealing of all the Linac tanks after 18 years of service. If there are no major incidents in 1997, this work will take place in the 1998 shutdown.

A new high energy optics was introduced during the year which resulted in smaller high energy transport losses and made the beam steering very much less sensitive to external perturbations. An optimisation program that can run in the background was used to refine the Linac optics and this resulted in a small, but useful gain in transmission. Both improvements contributed to the record intensities obtained in 1996. For the LHC era, a new 3-dimensional Bunch Shape Monitor (BSM) at 50 MeV was installed and commissioned, which allows bunch density measurements in all three dimensions.

4.2 PS Booster

During the annual shutdown, work concentrated on a systematic search for vacuum leaks in the Booster. This programme was crowned with success by the repair of a major leak on ring 3, which was especially important for the Pb-ion beam when an average of 1.9 10^{10} charges (the record was 2.7 10^{10}) of Pb^{53+} was accelerated during Run 3, about 10% more than the previous year. The shutdown also focussed on the installation of a new switching magnet between the line to the PS and the line to ISOLDE. This magnet is strong enough to bend protons of 1.4 GeV, the new Booster energy of the LHC era. Its increased length entailed displacements of neighbouring quadrupoles and recalculation of the beam optics. However, the re-commissioning of the line proved to be difficult, and operational settings still do not fully correspond to theory. The diagnostics of the beamline to ISOLDE was improved with an extra position monitor and current transformers immediately before each of the two targets, and later in the year SEM grid pairs for beam size and position monitoring were added inside both Faraday cages at the ISOLDE targets.

Acceleration of protons with the dual RF system, in particular for the high-intensity beams for SPS and ISOLDE experiments is always critical. Optimisation of the two RF voltage programs and of the relative phase of the four rings was time-consuming but finally successful. The result was that the PS reached a new intensity record. Comparing statistics one finds that 1996 Booster intensities are more than 15% higher over most of the year than their 1995 counterparts.

In parallel to operation for the PS the PSB now delivers proton beams routinely to both the GPS and HRS ISOLDE target areas. Solid targets frequently require maximum intensity on all spare cycles, and in 1996, the satisfactory figure of $3\ 10^{13}$ protons/pulse was often obtained or even exceeded. The "staggered" beam, designed to raise the intensity ceiling of liquid metal targets and featuring a gap of 10 μs between the sequential extraction of individual Booster rings, was produced repeatedly in tests; this mode will become fully operational in mid-1997.

4.3 PS and Transfer Lines

In the PS ring a new pulsed septum magnet was installed in straight section 42, to allow injection of the future Booster beam at 1.4 GeV, and a second, upgraded dump target was installed in straight section 98. As part of the consolidation and renewal programme, a new overhead crane handling 4 tons was installed in the PS tunnel to replace one of the original ones dating from 1954; the others will follow next year.

4.4 Machine Developments with Protons in the PS

Nine different beams were used during the year for studies and machine development sessions. As well as the well-established proton beams simulating Pb^{53+} and Pb^{82+}, beams were specially set up for LHC studies: for low-energy beam behaviour; for debunching and 40MHz cavity tests, and 25 ns bunch spacing; and for the dynamic aperture at 26 GeV/c and non-linear field effects on the transverse matching. Two beams were dedicated to SPS studies, with day-to-day modifications of the beam intensity, bunch length, and longitudinal emittance. One beam was used for careful measurements and optimisation of the tunes and chromaticities along the acceleration cycle. Finally a test was successfully performed to extract protons slowly at 6.6 GeV/c for a possible future hyperon experiment in the East Hall.

4.5 Kickers and Septa

In the course of 1996, 3 magnetic septa which had been running for 10 years since the beginning of LEP without major failure, developed leaks in their water cooling circuits. The first one, the EPA extraction septum, was repaired prior to the EPA start-up and was therefore without consequence for operation. The second one, however, the PS electron injection septum, had to be replaced and caused almost one week of interruption to LEP, as already mentioned. The third one, the PS positron injection septum, also failed during a LEP run but was kept running without water cooling thanks to the low repetition rate (one cycle every 14.4 s) and experience gained with the previous failure.

5. OPERATION WITH ANTIPROTONS

5.1 AAC

As the last year of operation of the AAC, 1996 proved to be an excellent one, with performances very similar to recent years, but with more operational hours achieved. The antiproton beam was available for 6259 hours with a 97% availability, and a total of 4.4 10^{13} antiprotons were stored, of which 2.35 10^{13} were able to be injected into LEAR. Most of the few faults that did occur were in the last running period, but fortunately they did not disturb the physics programme on LEAR very much.

In parallel with running AAC in "economy" mode, it was possible to make a number of studies aimed at the future AD project, where the AC machine is destined for conversion into an antiproton decelerator. Without making big changes which might perturb the run, it was possible to work on the control of the low-level radiofrequency to enable deceleration, on stochastic cooling at 2 GeV/c and on the closed orbits, with the result that deceleration with practically no losses from 3.5 GeV/c down to 420 MeV/c was demonstrated. This is a very significant step forward towards the AD project.

5.2 LEAR

LEAR's last antiproton year started out appropriately with tests aimed at its future rôle as an ion storage ring for LHC, when it will become LEIR. Then, after this 4-week period, the rest of the year consisted of long antiproton periods interspersed with short machine development sessions. The infamous "ghost" (when the antiproton beam in LEAR was often suddenly and inexplicably lost) was completely absent in 1996, due probably to an improved vacuum and the removal of equipment not needed for the 1996 runs. Electron cooling was used whenever the beam was below 310 MeV/c in order to improve the efficiency for the users, who received lots of high quality, long spills (up to 10 hours) on demand.

All in all, LEAR performed remarkably and will long be remembered as an interesting machine to work on. Its hallmark was its versatility. It was the first (and so far the only) machine to use stochastic cooling with variable energy, and to tame its beams even further at low energies with electron cooling. It provided extremely pure beams of antiprotons with an unprecedented flux, covering a wide range in momentum from 0.1 GeV/c to 2 GeV/c. It could produce an intense fast extracted bunch in one turn containing typically a billion antiprotons; or it could be tuned to ultra-slow mode to let the beam emerge to the experiments over a 15 hour period, corresponding to one antiproton leaving the machine every 10 turns. Precision experiments using an internal gas target became possible, where the cooling was instrumental in counteracting beam blow-up on the target.

6. OPERATION WITH IONS

6.1 Linac 3

Following the annual shutdown, Linac 3 was immediately used to provide ions to LEAR. These tests culminated with the demonstration of the possibility to ramp the output energy of the Linac by around 1%, which is necessary because multiturn injection into LEAR is planned in transverse and longitudinal phase space when LEAR becomes LEIR. Since the scheduled ion run was not till the third running period of the year, there were then several months during which preparations and improvements could be made. Both of the industry-supplied 100 MHz amplifiers for the tanks were finally commissioned, not without severe reliability problems. High field tests were performed on the IH tanks, and the result was a spectacular increase of the accelerating gradient from the nominal 6.4 MV/m to 9.3 MV/m. These results are very important for the design of future high gradient linear accelerators. Further tests are planned as soon as higher RF power can be made available. Finally, the Bunch Length and Velocity Detector (BLVD) was improved by the installation of a new RF deflector to double its bunch length range. Not surprisingly, this groundwork of preparation lead to an excellent ion physics run at the end of the year.

7. EXPERIMENTAL AREAS

7.1 LEAR Experimental Area in the South Hall

Eight experiments took data over the 34 weeks of LEAR operation, of which 26 required delicate setting-up when 2 or 3 experiments run simultaneously using splitter magnets. One third of the beam time was above 600 MeV/c. Slow extraction mode with beam momentum ranging from 105 to 1940 MeV/c was used most of the time, with the trap experiments PS196 and PS200 preferring fast extraction at 105 MeV/c. New optics were designed and commissioned for several of the beam lines: PS185/3 (Spin transfer) on line C1; PS205 (Helium trap) on line M1; and PS201 (OBELIX) on line M1, via X1.

7.2 Experimental and Test Area in the East Hall

The biggest item on the agenda for the East hall in 1996 was the study aimed at modifying the layout completely in order to provide a new 24 GeV/c primary beam line for a future new physics experiment (DIRAC), and to provide test beam facilities for components of LHC experiments. A new lay-out of the area was found, featuring a 24 GeV/c primary beam line, test places with secondary particles at 3.5, 7, 10 and 15 GeV/c, an additional irradiation area and an improved facility for beam sharing between the various users. The modifications in the hall should start in autumn 1997. Other work concerned the beam line t7 which was modified to transport the 3.5 GeV/c proton beam to experiment PS211, which uses a 300 ton lead block to study the phenomenology of spallation neutrons.

7.3 ISOLDE area

Preparation work in the hall has been done for the installation of experiments MISTRAL, NICOLE and REX.

7.4 LEA (Experimental Area at LIL)

LIL provided electron beams to LEA (LIL Experimental Area) for about 500 hours altogether. The beam was used by the experiment RD40 dealing with quartz fibre calorimetry, the objective being to test the radiation damage of the fibres, developed specially for this application. Different bundles of fibres were irradiated with doses varying between 10^4 Gy and 2 10^7 Gy, representing a possible version for the very forward calorimeters of the CMS and ALICE detectors.

7.5 EPA Test Area

The synchrotron light produced in LHC can be simulated by 308 MeV electrons in EPA (Electron Positron Accumulator). Several series of irradiations were performed in 1996 in order to investigate the behaviour of the induced gas desorption at cryogenic temperatures. This year the focus was on the recycling phenomena which will be experienced in LHC.

8. CONTROL SYSTEM AND COMPUTING

8.1 PS Control System

The first quarter of the year was devoted to upgrading the control of PS ejection systems and beam transfer lines in the frame of the D067 project. This new slice of the project was successfully put into operation, step by step, at the end of the shutdown: a new PPM (pulse-to-pulse modulation) operation scheme was introduced allowing 24 types of beams in the same PS supercycle; new injection and ejection timing systems were installed, based on the TG8 timing module developed jointly in PS and SL; new extraction system equipment on the PS (kickers, septa, double batch power supplies) and in the PS-SPS beam transfer lines (power converters, beam transformers and pick-up instrumentation) was tested and controlled for the different operations. In the Main Control Room (MCR), as well as in the local control rooms and equipment zones, some 60 new IBM RS/6000 workstations were installed, and all of the generic and specific operational programs were ported onto this new platform. A second batch of about 40 IBM workstations was received in July to complete the installation.

After the start-up of the machines, work could commence on planning the last slice of the D067 project. This slice consists of the upgrade of the general timing system and in finishing the controls conversion in a number of areas left out previously for funding reasons (PSB and PS power supplies interfaces, PS injection kicker, LPI instrumentation, LPI and PSB analog signal digitalization). An improved VME version of the Main Timing Generator (MTG) was produced in collaboration with SL-CO group and the IHEP Protvino Laboratory. The Linac 2, Linac 3 and PSB central timing systems were completely redesigned using the TG8 modules. A VME Timing Pulse

Surveillance Module (TSM) will complete this timing system renovation (in collaboration with TRIUMF laboratory). For the upgrading of the PSB main power supply, new regulation principles have been introduced and a mathematical model of the field in the main bending magnets is available, continuously cross-checked with NMR probe measurements. In December, tests were performed to validate the new principles: the VME based MTG was successfully tested in operation; the new TG8-based, timing system of Linac 2 was provisionally set up and used to produce beam; and beam was produced in the PSB, using the new main power supply regulation together with the field model driving the radiofrequency system.

With the final stop of the AAC machines at the end of the year, the last two remaining Norsk Data computers (for the AA machine and the PS Security system) were stopped and disconnected from the network. This ends the Norsk computer era at PS, started some 20 years ago. It also means that the whole PS control system will be completely homogeneous in 1997, once the LEAR ion tests are over.

A first study of the AD control system was launched on the basis of the current PS standard in order to produce a cost evaluation for the controls. During the Spring, a new study was launched as a collaboration with SL-CO and LHC-IAS groups with the aim of finding solutions common to the 3 Divisions. As a result, it was decided to introduce the PowerPC-based VME controllers standardized in SL Division. The proposal to use industrial PLC's for the simple power converters of AD (as used in LHC division) was not followed because of the lack of resources in the development period. A positive aspect of this common study was to reinforce the collaboration within the Accelerator Sector.

Contacts have been maintained with the EPICS collaboration by attending collaboration meetings (for architecture and applications), and by participation in the SOSH initiative (SOftware SHaring), especially with regard to support of CDEV (a portable equipment interface from CEBAF). In the frame of object-oriented technologies, the major part of the CO group's system libraries were migrated to C++ class libraries and a first set of "high-level" classes (Machine/ Process/ WorkingSet/ Archives) was integrated into the console manager for the start-up in order to use this technology to simplify the maintenance. The equipment access library was also re-engineered and re-implemented as a C++ class library to enhance the medium-term maintenance of this package. This development also provides the C++ programmers with a complete C++ applications program interface, and with documentation on the Web. The new version has been optimized with regard to memory usage. The connection with CDEV was completed, in order to provide connectivity with foreign applications whenever relevant. CASE tools have been introduced, so as to use models during the design and maintenance activities of the system libraries.

An efficient daily follow-up of the controls problems by the exploitation team made it once more possible to achieve a very good overall reliability this year due to highly standardized hardware and software solutions, applied to both Linacs, the PSB, LPI , the test beams and recently to the PS. Emphasis was put on the extension and integration of exploitation tools in order to cope with the complex operation schemes and the many concurrently-operated and frequently-changed beams. A new version of the Trigger Control Unit (TCU) was prototyped this year. This module was completely redesigned to cope with the extension of the PPM scheme to 24 different beam types. Finally, a new Web interface, which gives an easy access to the content of the database and to a fairly well-structured documentation, is felt to be major improvement; it contributes greatly to the easy maintenance and transparency of the control system.

8.2 ISOLDE Control System

When the Radioactive ion Experiment (REX) was approved as a major extension of the ISOLDE facility, it was decided that the simplest solution for the control of the different devices was to extend the existing ISOLDE control system, which had been provided by PS Division, using the same technology. As a first phase, the ISOLDE controls are being migrated to Windows 95, and this should be finished by the start-up in 1997.

8.3 Office Computing

The Division is well-equipped with office computers and has continued its upgrading policy so as to give them sufficient power and speed to cope with the latest programs, not only the routine administrative programs, but also those for engineering and design. We have been able to keep a homogeneous inventory of Olivetti PC's and are gradually phasing out Mac's for secretarial work in the groups. The Windows 3.1 operating system on the PC's is being progressively migrated to Windows 95 furnished by NICE, and this process will be finished in early 1997. The Division has profited from this move to Windows 95 to introduce a new version of the "printer wizard" to help people set up their network printing more easily. On the hardware side, the centralised CN printer service has improved the printers available on the network and removed the old "3812" printers. However, there have been many problems with network printing, attributed mainly to servers, although we have also felt the manpower constraints of CN, since pressure of work forces priority decisions which sometimes result in a long wait for the resolution of a printing problem. On the other hand, the introduction of structured cabling by CN was achieved with little disturbance in the Division, and will continue next year in outlying buildings.

With the arrival of NICE95, remote access to the control system benefited from the improved automatic call-back (ACB) facility supported by CN Division. As a result, remote diagnostics and set-up of PS equipment has been increasingly used, relying on a dedicated set of diagnostic and documentation tools.

8.4 PC connectivity to the PS control system

The gateway, or "passerelle", which guarantees a controlled access from the PC platform to the PS control system, has been installed on a dedicated IBM RS/6000 machine in order to improve its reliability and response time. Over the last 50 days of 1996, the gateway handled about 6.8 million requests. This growing interest from the users and the introduction of NICE95 has forced us to upgrade the communication mechanism. The new Windows 95 client control system interface solved the performance problems encountered by the old Windows 3.1 mechanism, and Object Linking and Embedding (OLE) has replaced Dynamic Data Exchange (DDE). An OLE object (called OCX) has been designed which facilitates the development of applications accessing the control system; this object is a piece of software, built on top of a low level Dynamic Link Library containing all the properties needed to access the equipment. It can be easily inserted into an Excel, Visual Basic (VB) or C/C++ application without any programming. An alternative approach to accessing the control system is through the World-Wide Web, using intelligent browsers like Netscape or Microsoft Internet Explorer. OLE combined with VB scripts can be used with Microsoft Internet Explorer, but Netscape requires the development of appropriate "applets" in the Java language; it is not yet clear which approach will be the more suitable.

A special version of the Windows NT server, manufactured by NCD Wincenter Pro, has been installed to provide access to Windows programs from the X-Windows environment. This was necessary for the controls exploitation team and for the MCR operators, to be able to run Microsoft-based diagnostics programs or application prototypes from workstations and X-terminals.

9. BEAM DIAGNOSTICS

Apart from the never-ending task of maintaining the hardware and software of the ever-growing number of diagnostic devices around the PS, much effort was invested in the consolidation programme. This meant not only replacing decades-old equipment by new and standardised modules, but also providing increased performance and flexibility, in line with the capabilities of modern electronics. The programme of converting the PS complex to its rôle as LHC injector confronted us with similar challenges, as did requests from PS users at ISOLDE and in the experimental areas. All this work of course was done in the context of the ongoing conversion of the controls system, introducing the VME standard wherever possible and demanding wide-spread effort for the creation of specific software, i.e. for data acquisition and treatment, and conversation with the controls system.

The measurement of PS beam intensity by means of beam transformers was rationalised such that all values, wherever used or displayed, now stem from the same source. Similarly, the beam intensity measurement for leptons at LIL and EPA was renewed and streamlined. In response to a request for "staggered" proton ejection from the Booster towards ISOLDE, work was started on an entirely new acquisition and timing system for all fast beam transformers between Booster, PS and ISOLDE. At the same time, laboratory work continued on identifying the basic resolution limits of DC beam transformers, and considerable progress was made. The importance of spectral purity of the modulator current was recognised, and subsequently improved, which will also benefit the LHC. New heat- and radiation-resistant SEM-grids, developed in 1995, were installed in front of the 2 ISOLDE targets. They, together with a new pick-up and 2 new beam transformers, have much facilitated the critical setting-up and routine operation of this high-intensity line.

For the closed orbit measurement system of the PS (comprising 40 pick-ups), new specific controls were developed to provide more flexibility and to prepare the ground for future modes of operation. The opto-couplers in the tunnel frequently die from radiation, and so new inductive couplers were introduced to replace them. In the transfer lines leading away from the PS, and between AAC and PS, the position pick-ups traditionally shared an antiquated controls system with the beam transformers in the same lines, but they have received new head-electronics and modern specific controls and are now capable of measuring individual bunches over the intensity ranges of all types of beam. This is a significant improvement.

A major step forward was also made by putting into service a new system of electronics, acquisition and timing for the position pick-ups in the transfer and recombination line from the Booster to the PS. Not only did the 15-year-old, radiation-damaged electronics get replaced, but the new system now delivers impeccable data and signals, whilst the old ones were heavily perturbed by secondary emission under the frequent condition of beam loss in this region. The new electronics also adapts automatically to all kinds of modes of operation and intensities. New electronics is also the key to studies which were begun towards a renovation programme for the more than 100 stations which observe beam position and size by means of scintillator screens and TV cameras. Triggerable cameras and modern signal acquisition and image treatment electronics are being looked at to find an economic way to renew and improve this very old system.

10. CONSOLIDATION WORK AROUND THE PS

10.1 Consolidation of the Proton Programme

As part of the modernisation programme, and in the context of the new control system for the PS, around 70 power converters were upgraded for ejections 16, 58 and 61 as well as for the transfer lines TT16 and FA58. Supplies for low energy correction in the PS, dipoles for the PSB and bendings BHZ20, 25, 30, and 40 in the Linac-to-PSB line are also being prepared to receive new standard electronics to match the new controls. Studies for new low energy correction supplies have been started in collaboration with the University of Valencia, and specifications have been prepared for the "shavers" and "beamscope" supplies. Furthermore studies are under way with the University of Padua concerning AC and DC filtering in switch mode power supplies.

Elimination of equipment containing PCB was again necessary in 1996. The capacitors of the "Tekelec" supplies and the capacitor banks of the DC filter of the PS magnet main power supply were changed, and the transformer of the SMH57 supply was replaced by a dry transformer. Only the Booster power supply and the main LEAR supply now contain PCB which has to be eliminated to comply with the latest legislation.

Another consolidation activity was preparation for the refurbishing of the rectifier buildings around the East hall, including a complete rejuvenation of the 18 kV substation 11 and the low voltage distribution. Eight new R3 power converters were ordered from industry and another five were recuperated from the South hall. These will power the magnets in the East hall needed for the new layout to be installed in 1997.

10.2 Renovation of the PS Cable Network

It is 40 years since the construction of the PS machine, and for 40 years cables have been laid progressively in the cable tunnels as other machines were added. In the meantime, equipment was modified to new standards or replaced, most often leaving all the old cables behind. Documentation on the cables became harder to find as people left CERN, and only the newest installations were included in the CERN cable database. Also, the cable trays themselves were often sagging with the load, and access holes to buildings were completely blocked, making it impossible to install new cables by that route. The desperate situation was highlighted in a survey by ST Division, and it was realised that we needed an urgent clean-up. Work has started on documenting the cables and trays, correlating this with the civil engineering drawings so that in future, cable routes can be calculated with the standard software available in ST-IE group. In the shutdown, work started on removing old cables in certain areas, notably the connections between the PS and the central building, work which can only be done in a shutdown. The intention is to tackle this renovation in each shutdown for 5 years until the whole complex has been cleaned. Great care has to be exercised to ensure the security of the people removing the cables, who must ensure that those cables which are to be left in place are not damaged. This year, a specialist team of 20 people removed over 200 km of old cables.

11. PREPARATION OF THE PS FOR PROTONS FOR LHC

The project to convert the PS complex to an efficient and reliable LHC pre-injector reached several milestones in 1996. It should be noted that the TRIUMF laboratory, in the framework of Canada's contribution to LHC, has already made major contributions (in both hardware and know-how) to many of the systems being modified. The main areas of progress in 1996 were:

1. RF systems for the PSB (h=1): the prototype cavity has reached more than the nominal voltage of 7 kV and is ready for installation; orders for ancillary equipment of the 3 other cavities have been placed in Europe and Canada.
2. 40 MHz RF system in the PS: the prototype RF cavity is installed and has reached its design voltage of 300 kV; an LHC-type beam could indeed be bunched with 25 ns spacing, as was demonstrated in a very important series of tests, with the result shown in Fig. 2; the Canadian high-voltage supplies (9 and 24 kV) have also been delivered.
3. 80 MHz RF systems in the PS (to shorten the bunches to 4 ns): Measurements on a wooden cavity model in TRIUMF essentially confirmed the calculated shape, including tuners and higher-order-mode (HOM) dampers; the mechanical structures are being worked on in CERN with a view to install 2 cavities in the 1998 shutdown.
4. Main magnet supply for the PSB to reach 1.4 GeV: orders for PCB-free transformers (10 x 1.34 MVA) as well as the 18 kV reactive power compensator have been placed with Canadian industry; the design and prototyping of a new current regulation and controls interface for these supplies has been accomplished, which will increase the accuracy and

reproducibility of the magnetic cycle by nearly a factor of ten and make it much easier to create and modify magnet cycles, as tests with beam demonstrated in December.

5. PSB-PS transfer line to 1.4 GeV: orders for about 20 magnets (quadrupoles, benders, and correction dipoles) have been placed in Canada, as have those for the modern switch-mode power converters for these elements, using IGBT semiconductor switches at 20 kHz which will enable the line to be switched between two different energies, from pulse to pulse; one of the vertical recombination septa (BTSMV20) and its pulsed supply have been made in CERN and are ready for installation; and a 20° bending magnet to guide the beam towards the PSB measurement and ISOLDE lines was replaced by a more powerful, laminated one, although necessitating new optics for both lines, as already mentioned.

6. PSB water cooling system: in line with CERN's ecological initiative to save scarce resources like fresh water, a closed-circuit system is proposed; the building to house cooling towers, pumps, heat exchangers, etc. is under construction; with this new system, the PSB main magnet temperature will rise from 20° to 27°C, but a one-week test in Summer 1996 did not reveal any detrimental effects of this on the beam.

7. Beam diagnostics: a prototype fast wire scanner is now installed in the PSB and is awaiting tests, in particular at low beam energy; a fast-moving blade beam profile monitor is being developed in TRIUMF; finally, two wide-band position monitors are being assembled which will permit observation of the short bunches (4 ns) on their way to the SPS by 1998.

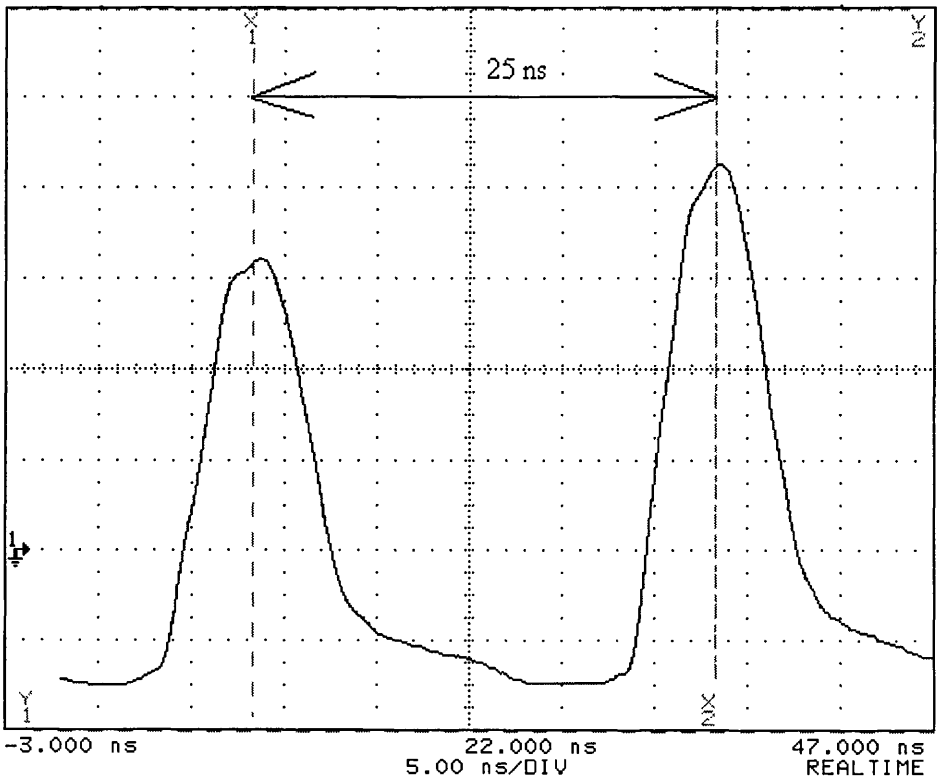

Figure 2
The PS beam bunched at 40 MHz (but note that the bunch lengths are too long for LHC because there is as yet no 80 MHz cavity).

12. LEIR, STUDIES WITH IONS IN LEAR FOR LHC

Tests of storage and cooling of lead ions in view of the accumulation of intense bunches for LHC were continued with a one week run after the annual shutdown. The main investigations were concerned with: the lifetime of stored and cooled lead ions; the dependence of the cooling on the lattice parameters of the storage ring; and preparations for multi-turn injection and accumulation. The aim was further to test the techniques and to determine what modifications are necessary to LEAR for the final tests in 1997, following its closure for antiproton work.

The results were very encouraging. A lifetime for Pb^{54+} ions compatible with an accumulation over 2 to 3 seconds was firmly established. The anomalously fast decline of Pb^{53+} ions in the presence of electron cooling was confirmed, but all the neighbouring charge states (52+, 54+, 55+) were found to decay at least 5 times slower. This recombination with cooling electrons is not understood, but charge exchange with the residual gas was further investigated and it was confirmed that a high quality vacuum is indispensable for accumulation. Special optical settings to reach the required fast cooling times of order 100 ms were determined, at least for the relatively low beam intensity available (about 10^7 ions instead of 10^9 in the final project). Multi-turn injection was not possible in the configuration for ultra slow extraction needed by the LEAR antiproton users, but tests of the "energy ramping" of Linac 3 and of the special "large acceptance tuning" of the transfer line were successfully carried out. Both are required for the novel transverse and longitudinal multi-turn injection into LEIR. On the basis of these results, the modifications necessary for next year were clear.

13. COMPACT LINEAR COLLIDER STUDIES

13.1 CLIC

The single bunch target parameters were updated during the year to give a higher luminosity to power ratio for the same beam-strahlung parameters and experimental background conditions. This was achieved in two ways, first by reducing the single bunch emittance blow-up by doubling the number of quadrupoles, increasing the accelerating gradient to 100 MV/m, reducing the bunch length to 160 μm and invoking the use of a new trajectory correction algorithm, and secondly by improving the efficiency of RF power generation. With these new parameters the single-bunch vertical emittance blow-up is relatively small (65% compared to 300% with the previous parameters). A revised CLIC parameter list was issued in August 1996 with luminosities of 6.85 10^{33} cm^{-2} s^{-1} and 1.5 10^{34} cm^{-2} s^{-1} for the 500 GeV and 1 TeV centre-of-mass machines with 20 and 30 bunches respectively. In multibunch operation, final normalised vertical emittances of 10 and 12.5 10^{-8} m.rad are assumed for the two machines, and pre-suppose the existence of an accelerating structure adapted to multibunch operation. Such a structure has not yet been developed but is the subject of ongoing studies.

The main part of the beam dynamics work has been devoted to single and multibunch emittance preservation studies in the main Linac. Existing programs have been modified for this purpose and include in many cases an animated graphic output capability. Multibunch simulations using wakefields calculated for different accelerating section models have established the levels that are needed to avoid significant emittance growth and have enabled the sensitivity of small variations of the scaling of focusing with energy to be studied. Although a scheme to apply the principle of BNS damping to multibunch operation (developed in collaboration with the University of Madeira) has been shown to be theoretically feasible, its practical implementation is considered too complicated. A new powerful correction scheme based on dispersion and wakefield-effect direct measurements has proved very effective in reducing the vertical emittance and has been successfully applied to the new lattice layout in sectors. Using the latest optimised corrections, the single bunch emittance blow-up has been reduced to about 20% for rms alignment tolerances of 10μm. A new and general method has been developed for the statistical analysis of the dipole wakefield effects on a high energy charged particle beam. Starting from a given probability law for the misalignments of the beam line components, a given trajectory correction scheme, and a given focusing lattice, the statistical distribution laws of beam-related quantities such as emittance blow-up are computed. The advantage of this approach compared to classical methods which generate their statistics by making several runs with randomly generated misalignments, is the ability to generate statistical results in one passage (it does however require the pre-calculation of a very large number of response coefficients and large matrices). This new method has been used to reconsider the possibility of providing BNS damping via energy spread rather than by using time-dependent microwave quadrupoles. First results using the natural beam loading energy spread are encouraging and this approach is being pursued.

A new drive beam generation scheme based on 250 MHz LEP2-type superconducting cavities has been devised for a 26-bunch mode of operation in the main Linac at 1 TeV. The 3 GeV drive beam for each drive Linac is generated by an in-line upstream Linac pair. The total installed voltage (for two drive beams) is 18.5 GV. The use of 250 MHz cavities was necessary to have enough stored energy available to accelerate the required charge of 30μC / drive beam. The charge is distributed in trains of 30 bunches with a spacing between bunches of 1 cm and a maximum charge of 50 nC/bunch. There are 2 trains per 250 MHz RF period and the entire drive beam extends over 11 periods. A low impedance (4 Ω/m) energy-extracting transfer structure provides an input power of 102 MW which is fed to two accelerating structures. In this scheme one drive beam is used to produce power for the total length of the main Linac. The resulting overall "mains plug to beam" efficiency is 10.5%. The short intense bunches for this scheme are generated either by combining the outputs of a battery of 10 S-Band Linacs, or by the direct bunching action of a 30 GHz FEL (free electron laser). This latter option is being studied at the FEL Test Facility at CESTA (Bordeaux) within the framework of a CERN(CLIC)/CESTA collaboration. The first direct observation of beam bunching by a high power microwave FEL was made this year at this facility using the 1kA 2.2 MeV induction Linac LELIA as a power source. The extent of beam bunching was measured optically by analysing the Cerenkov radiation produced by the beam hitting a silica target placed at different on-axis positions at the exit of the helical wiggler.

An alternative multi-drive-beam scheme has also been studied. In this scheme each drive beam is used to power a short section of the main Linac. Using 20 drive beams with an energy of about 1.5 GeV, a total charge of 6.4 μC per drive beam is required for a 30 bunch mode of operation in the main Linac at 1 TeV. In this case each drive beam consists of one long continuous train of

488 bunches with a spacing of 3 cm and a maximum bunch charge of 15 nC/bunch. The bunches for the 20 drive beams are generated in a laser-driven RF gun and accelerated by TESLA-type 1.25 GHz superconducting cavities. The total installed voltage in this case is only 2.2 GV. The bunches are first stored in a 20 km long collector ring and are then combined in stages to obtain the 3 cm spacing. A detailed analysis of a symmetric triplet for possible use in this ring has been made. The impedance of the energy-extracting transfer structure is around 100 Ω/m. The over-all "mains plug to beam" efficiency of this scheme is 11.8%.

A third drive beam scheme is being studied in collaboration with LLNL/LBNL laboratories. The idea is to use Relativistic Klystron Two-Beam Accelerator (RK-TBA) units as RF power sources for a CLIC-type Linac at 30 GHz, with each unit providing RF power for 300 m of main Linac. The average initial drive beam energy in this case is 10 MeV. The design makes use of magnetic pulse-compression units driving ferrite-core induction cells and claims "mains plug to beam" efficiencies in excess of 20% for a large number of bunches in the main Linac.

An important parallel and necessary activity to confirm the validity of the above-mentioned drive beam studies has been the beam dynamics simulations of the behaviour of bunched beams in their associated power-generating drive Linacs. New simulation programs have been written for this purpose. In all schemes it is assumed that the beam is dumped at an energy of 200 MeV. For the high impedance scheme it has been shown that the beam can be made to reach the end of the Linac by assuming a 50% damping of the multibunch transverse wakefields, and by alternating the energies of sequential bunches by ± 3.5%. For the low impedance scheme the beam can be made to survive with no wakefield damping but requires alternating the energies of sequential bunches over the first few trains by ± 2.5%. Estimates have been made in collaboration with CEBAF of probable beam loss levels and the resulting heat loads, and solutions are being proposed to deal with them.

Design studies of main Linac accelerating structures for multibunch operation are continuing. The RF design of a structure damped with four T-cross-section waveguides per cell has been completed. The wakefield behaviour was investigated using time domain MAFIA computations over 20 cells for frequencies up to 150 GHz. The transverse wakefield levels calculated have been used in main Linac beam dynamics simulations to demonstrate the feasibility of a 30 bunch operation at 1 TeV. Unfortunately this design will probably be abandoned due to insurmountable fabrication problems. It was also discovered during the year that the transfer structures require damping to reduce long-range transverse wakefields in the drive Linac. This problem has been investigated using both model tests and MAFIA calculations. By making radial slits in the cross-section of the existing design, it has been possible to achieve a 30% reduction in the wake effect with a new prototype structure.

Studies by Monte Carlo simulations of background events in the CLIC interaction region have been made using three different input generator programs (ABEL, GUINEA PIG, and LINCOL). The detector is assumed to have a LEP-like central three-layer silicon vertex detector within a 2 Tesla solenoidal field. Conical masks covering an angle of 150 mrad are assumed to contain back-scattered electrons and synchrotron radiation. The LINCOL program was written within the framework of a CLIC/Novosibirsk collaboration. Although it is not the intention of the study to propose the construction of a machine in the near future, some effort has been also devoted to costing the main parts of the CLIC scheme. This information is used mainly to identify the relative importance of the various costs rather than to estimate their absolute values.

13.2 CTF2

A considerable fraction of the CLIC effort during 1996 was devoted to CTF2, the new two-beam test facility . The overall design has been completed and a design report published. Beam dynamics studies of the drive Linac using PARMTRACK revealed a serious transverse wakefield problem which was resolved by introducing damping in the transfer structures, and by the use of new optics. The two new 3 GHz drive and probe beam generator Linacs were installed and operated. The drive Linac has a new 2 & 1/2 cell RF gun and for the moment is being operated with the old CTF1 NAS accelerating section. Two new High Charge Sections (HCS) are being constructed and will be installed in 1997. The newly configured bunch compressor has been installed and tested with single bunches. The probe beam Linac consists of the old CTF1 1 & 1/2 cell RF gun and a spare 4.5m long LIL accelerating section. The operating time of CTF2 this year was shared between component testing and commissioning of the beam lines, and beam physics experiments. Some results were as follows: the probe beam RF gun was conditioned to 80 MV/m and produced the nominal single bunch charge of 1.3 nC, whereas the drive beam RF gun reached 92 MV/m and produced single bunch charges in excess of the nominal 13.4 nC design value; an automatic RF conditioning system was developed and tested successfully; a CsI photocathode with a 2 nm layer of Ge to lower the work function operated with a quantum efficiency of 0.2-0.3% for more than 2 weeks in the RF gun of the probe beam Linac; measurements failed to confirm a theoretically predicted significant growth in emittance due to coherent radiation effects of short intense bunches transiting an achromatic bend, in this case the bunch compressor; a new 30 GHz beam position monitor (BPM) measurement system was tested, built to minimise angular jitter effects, and consisting of two closely-spaced resonant cavity BPM's and a charge normalisation/phase reference cavity; tests with the newly configured bunch compressor produced nominal bunch lengths of 5 ps (FWHH) for the nominal bunch charge of 13.4 nC.

All the necessary equipment for the first two actively-aligned 1.4m long modules of the 30 GHz two-beam accelerator for CTF2 has been designed and either delivered or fabricated. These components will be mounted on a test platform in building 169 before final installation in CTF2. This was deemed necessary because of the high component density and complexity of the set-up. This test platform will be used in the future for alignment and control studies. Two new high performance instruments, a capacitive biaxial wire position monitor and a capacitive three-axe tilt monitor, have been specially developed by industry in collaboration with CERN for the active alignment system, which uses a stretched wire as a spatial reference. Much of the basic design development work for the alignment control has been completed and implemented, partly in collaboration with the University of Mar del Plata, Argentina. A full working mechanical test of the test platform is planned for June 1997.

Laser stability has always been a concern of CTF. Two techniques, the fast forward method and the direct charging method, have been proposed to regulate the pulse to pulse energy jitter. The first, the feed forward method, has been successfully tested. The second method is for the moment limited by the capacity of the photodiode which charges the pockel cell. A new double-pass amplifier with increased gain has been developed for the Nd:YLF laser in preparation for a future four pulse operation with an associated reduced risk of damage to the optical components.

A new 2 & 1/2 cell photo-electron RF gun has been designed for CTF2 to produce a charge of 1µC in a train of 48 bunches. The extracted beam energy of 6.5 J leads to a pronounced decrease in the field gradient. In order to reduce the effect of such a strong beam loading, albeit at the expense of a moderate increase in RF power, the first half cell has been chosen to be a TM_{02} resonant cell, the two others being standard TM_{01} cells. Construction of this new gun is foreseen for next year.

14. THE ANTIPROTON DECELERATOR STUDY

Throughout the year, intensive studies were carried out to establish the feasibility and cost of an Antiproton Decelerator (AD) facility. AD is a low cost scheme for filling traps with antiprotons at rest, based on the existing antiproton source, with collection in a modified version of the Antiproton Collector (AC). Early this year, the low energy physics community showed a keen interest in such a machine and the AD Users Committee (ADUC) was set up. Its mandate is to look for the external funding needed, to organise the required external manpower and material contributions, and to act as a filter between the AD user community and the SPSLC. Following the first meeting in September, a paper describing the various tasks was published. The design report of the machine was also published, showing in particular the new lattice proposed, taking into account the insertion of the electron cooling device.

In parallel with normal AAC operation for LEAR antiproton physics, many machine studies were carried out. These showed the necessity of correcting the closed orbit during deceleration, that the vacuum and the ring power supply regulation during ramping must be improved, and that fast Schottky tune diagnostics during bunched beam deceleration should be implemented. With the help of a new digital radiofrequency system (whose frequency was programmed by a B-train derived from a ring bending magnet), and a lot of work on the power supply stabilisation, the lowest momentum achieved was 420 MeV/c. The reasons for this lower momentum limit were clearly identified and understood: poor vacuum, poor trim supply regulation at low currents, reduced acceptance due to lack of dynamic orbit correction, and too low a deceleration rate due to lack of a proper function generator and inadequate current regulation during ramping. The studies were extremely important because they confirmed the feasibility of the AD project and should ensure a smooth commissioning of the machine in 1998, with no major surprises.

15. LASER ION SOURCE STUDIES

The long-awaited RFQ for the Laser Ion Source (LIS) became operational in 1996. It was constructed principally in the CERN workshops, where the copper plating was also done. After RF tuning the device was tested with proton and helium beams of the same input velocity as the nominal heavy-ion beam, and a transmission value of 88% was found, in good agreement with simulations. Final tests in conjunction with the laser source with different ions up to Pb showed good voltage holding capability, but less than anticipated intensity due to matching conditions in the LEBT (low energy beam transport section). Nevertheless, with currents at the entrance to the RFQ of 10 mA (and even a peak of 19 mA) of a mixture of 6 charge-states around Ta^{20+}, accelerated currents in the mA range of single charge state Ta^{20+} were obtained in a 5 μsec pulse at an energy of 100 keV/u. Similar currents of Pb^{23+} were also observed. These very encouraging results were achieved in collaboration with Russian, Czech and Polish institutes, and augur well for the future. An application has been made successfully for ISTC funds to construct a 100 J laser-power amplifier in Russia, and preparations are in hand for the construction of a "master oscillator" to drive it.

16. ABS STUDIES

In view of the production of bright beams for LHC, the PS complex is implementing an automated control of the various optics manipulations a proton beam is submitted to between the source and its transfer to the SPS. The acronym of the project, ABS, stands for Automated Beam Steering and Shaping. So far only the steering function has been treated, and operational applications are running for the transfers between Linac, Booster and PS, for the PS closed orbit, for PS coherent oscillations, and for the beam positioning on the various emittance measurement monitors. A database of machine parameters has been designed, together with a selector which links it to the optics programs. Tests of the system have already revealed where there are some weak points and misalignments, and an important result was achieved with the complete revision of the optics of the Linac-to-PSB line to achieve far smaller losses.

17. COLLABORATION WITH IHEP

17.1 UNK Beam Diagnostics

Due to the uncertainties surrounding the UNK project, activities during 1996 were limited to a single visit from an IHEP expert and the subsequent procurement by CERN of material to finish off deliveries of laboratory instruments to IHEP. The reorientation of the remaining funds earmarked for this activity, either towards U70 beam diagnostics or to U70 controls, was the subject of repeated discussions.

17.2 Controls Collaboration

This year was the first since the redefinition of the IHEP Protvino project as an upgrade of the U70 complex controls, spread over a 3- to 4-year period. The U70 complex consists of a Linac, a booster and main synchrotron ring, fast and slow ejection systems, target area and beam transfer lines. These systems have no common control system and are controlled locally from control rooms situated in different buildings; they exchange a limited amount of operational information in an heterogeneous manner. Much of the equipment is in fact manually controlled, and where there are computerised controls, the computers used are obsolete and can no longer be maintained.

The first half of the year was dedicated to a review of the technical proposal and of the detailed planning. The International Review Board met in May at CERN to assess the proposal, which was very positive and was well supported. However there are some concerns over the time scale as presented. The rest of the year was used to finalise the hardware and to start production. Prototypes of the major software packages were developed in close collaboration with the various IHEP departments involved in the project. There was a very active technology transfer with CERN, and close collaboration with PS and SL Divisions was an essential feature, as was the presence at CERN of an IHEP project manager. A very close involvement of IHEP top management is a very positive move to ensure that the project develops smoothly.

18. Linac96, XVIII INTERNATIONAL LINAC CONFERENCE

Invented in the late 1920's for fundamental research, linear accelerators are mainly used as injectors for circular accelerators. Increasingly they are now used in industry. Applications include medical diagnostics and radiotherapy, material investigation and sterilisation of equipment and food. A further extension of their industrial application currently being investigated is a possible use for energy production and transmutation of nuclear waste. Linear accelerator builders and users have organised bi-annual International conferences since 1961, all except two of which took place in North America. So, it was a great honour for CERN to have been chosen to organise the 18^{th} in the series at the Penta Hotel in August 1996. Many specialised CERN services collaborated in the organisation, and there was a large participation by PS staff.

The conference was attended by 319 participants from 16 countries. At the International Organising Committee meeting held in Dallas in May 1996, there was a strong desire to have an industrial exhibition, and this was duly organised, with ten exhibitors from various countries. The general format of the programme followed the traditional pattern of this conference series: morning sessions with invited talks, afternoon poster sessions, and no parallel sessions,. There were altogether more than 120 proposals for invited talks to the International Advisory Committee and the Programme Committee. That, and the steady extension of the field of electron and ion accelerators, led to the decision to introduce 20-minute talks as well as the traditional 30-minute presentations. This allowed a total 40 invited papers to be offered, and there were in addition 231 poster papers accepted. Electron and ion topics were almost equally represented among the invited talks and these were smoothly mixed in the sessions. WWW was used extensively for dissemination of information before the Conference.

Following the modern trend, we decided to publish the proceedings of the Conference in three forms, two of which were used for the first time at a Linac Conference:

1. The traditional paper version which was sent out in mid-December 1996, less than 4 months after the Conference, which is probably a record.

2. An electronic version which was available on the World-Wide Web very soon after the Conference.

3. A high quality electronic version on a CD-ROM to be sent out in January 1997.

As part of the proceedings it was decided to prepare a Compendium of Linacs, last published in 1976. A provisional version was prepared before the Conference and the corrected version was sent out together with the paper proceedings. It presented data on a total of 176 "scientific" Linacs in the world, with 61 in America, 37 in Asia and 78 in Europe; medical and industrial Linacs were not included.

Like any conference, Linac96 had its lighter side. There was a welcome cocktail on Sunday evening, and on Wednesday afternoon an excursion to the region of Gruyère, with dinner in the ancient castle of Oron. The traditional conference dinner took place in the Mövenpick Hotel on Thursday evening, starting with a talk by Edward A. Knapp on work done at the Santa Fe Institute, entitled "New Directions for Science"; the State of Geneva and the Commune de Meyrin were represented by Philippe Joye, and Madeleine Bernasconi respectively. Finally, to close the Conference, a visit to CERN was arranged on Friday afternoon, with a short introductory talk by Kurt Hübner, Director of Accelerators. A guided tour for 250 people, stretching the CERN visits service to its limit, allowed the participants to see Linac 2 for protons, Linac 3 for Pb-ions, the LIL Linacs for electrons and positrons, and one of the LEP experiments.

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