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THE ACTIVITIES OF THE PS DIVISION IN 1991

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with major contributions from the PS Staff

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1. Introduction

1991 has been a year with continued and consolidated use of the PS Complex as a source of all particles at CERN. With nine different accelerators and storage rings, the Complex has gone through the year with a full and varied physics support programme ranging from electrons and positrons for LEP, antiprotons for LEAR and the SPS Collider and protons, oxygen and sulphur ions for the SPS fixed-target physics. The year ended with the first ever beam in the transfer line from the PSB to the newly constructed ISOLDE facility, auguring well for the commissioning and routine operation of this new facility planned for 1992. All this was achieved with reasonable accelerator reliability and availability for physics, despite diminishing human resources and consequent increase in workload of remaining staff.

Various accelerator related R & D activities have continued, notably for the construction of the lead ion linac, CLIC and its Test Facility CTF, laser-driven ion sources and lastly, to enable the Complex to function as an injector for the LHC. In addition, the Division has contributed to the general LHC Design Study for beam diagnostics, beam loss detection for quench protection as well as for the LHC detectors as part of the proposal to develop position sensitive photomultipliers coupled to scintillating fibres. The Division has also contributed to the studies to evaluate the dynamic aperture of the LHC, with extensive use of tracking programs. The Division's expertise has been sought for the design of new accelerators in Europe and for concepts including the accelerator driven inertial fusion as a novel energy source. The control system for the ISOLDE facility was developed for the PPE Division, using the PS office network, PC's and PC-based commercial hardware and software for controls. Various other laboratories, universities and industries have shown great interest in this development, with adoption to their environment.

Table 1 to 4 and Fig. 1 illustrate the breakdown of year's operation of the Complex while Fig. 2 shows some of the highlights. Fig. 3 indicates the evolution of peak intensities of protons, electrons, positrons and ions while Fig. 4 gives a recent illustration of the new ISOLDE layout in the vicinity of the PS Booster.

2. PS Complex Operation

The year's operation comprised five running periods separated by short shutdowns. The first short period before Easter in March was mainly devoted to the general start-up of the PS Complex followed by those of SPS and LEP. The subsequent two long operation runs were used for physics at LEP, SPS fixed-target experiments and LEAR. During the 4th period in autumn, sulphur ion beams replaced protons for fixed-target physics. The year ended by a short period devoted to antiprotons at the SPS Collider and LEAR.

The year commenced with a long, two month winter shutdown dedicated to preventive maintenance and various installation activities in all the accelerators of the PS Complex. These included civil engineering and installation of the transfer line from the Booster towards the new ISOLDE facility, renovation of half of the water cooling circuits in the PS, continued installation of the new slow extraction scheme, replacement of several elements of LIL (gun modulator, prebuncher and buncher) and installation of the prototype plasma lens in the AAC target area for a short test. The last week of February was devoted to numerous equipment tests, most of them being carried out during the evenings after the safe and secure closure of the accelerators concerned.

The first operation run started on 4th March; the different beams were successively adjusted during the first two weeks, encountering and overcoming the classical problems that occur at each accelerator start-up. The proton and lepton beams were delivered in time to SPS and LEP during the 3rd and 4th week. For the SPS start-up, the PS provided two batches of 8×10^{12} protons delivered in the continuous transfer mode, using the first two cycles of the 14.4 s supercycle. The usual last four cycles were dedicated to lepton beams with about 6×10^{10} particles in four bunches. In parallel, tests at higher intensities were carried out on both types of beams in order to prepare for the operational conditions requested for later in the year by the SPS and LEP. The East Hall also received from 18 March onwards proton spills using the PS slow extraction scheme. Several accelerator study sessions were also carried out during this run.

The second period lasting three months started after the short Easter shutdown. Over this long run, the availability of the PS Complex for SPS/LEP was about 94% for the proton beams and slightly lower (~88%) for the leptons. LPI was especially affected by many problems, namely, numerous modulator breakdowns, controls and power supply faults, water leaks, water cooling problems and a water leak on the solenoid used for positron focussing. The PS also suffered from several interruptions due to power supplies, general time-sequencing and controls.

The third run over the summer months was similar to the previous period with the same clients of the PS Complex. Over this run the availability for lepton beams was of the order of 87% and 93% for the proton beams. Several major problems affected the different beams i.e, 130 kV failure, thunderstorms, breakdown of a water pipe in the LPI, timing problems and the exchange of the PS 1 GeV injection septum magnet after a vacuum leak, causing an interruption of 24 hours. During both these long periods, the PS delivered to the SPS-LEP average intensities between 2.1×10^{13} and 2.4×10^{13} protons/batch and 8×10^{10} leptons per cycle (two e^+ and two e^- cycles). During these six months, LEAR operated at different energies for eight different experiments in the South Hall: Jetset at several energies between 1200 and 2000 MeV/c, anticyclotron test at 72 MeV/c, CP violation and Crystal Barrel at 200 MeV/c, antiproton trap at 105 MeV/c, antiproton mass at 61.2 MeV/c, Obelix at 309 MeV/c and later at 105 MeV/c and Helium Trap at 105 MeV/c.

AAC started well with the 20 mm Li lens for antiprotons collection but unfortunately, a serious fault occurred during the second week of April and it was necessary to stop the antiproton production for six days; after two days of radiation cooldown, the Li lens was removed and replaced by the 400 kA magnetic horn. LEAR did not suffer too much from this interruption due to a sufficiently large antiproton stack produced and stored earlier. The AAC performed well subsequently, with a mean accumulation rate of 2.6×10^{10} antiprotons/hour, with two production cycles in the PS supercycle. Since LEAR was the only client and depending on experiments, the AAC often operated in the energy-saving economy mode. In this mode, after an accumulation of 5×10^{11} antiprotons, the stacking process was normally stopped and the AC ring switched off; deliveries could continue from the AA stack. On the PSB and the PS, the principal accelerator studies were concerned with the preparation of the bright proton beams for the LHC, monoturn injection in the PSB with high Linac2 currents, dispersion matching in the PSB-PS transfer line, transverse beam behaviour in the PS and the debunched beam instabilities at 26 GeV/c. Two combined accelerator development sessions in Linac1, PSB-PS and the SPS were partly used for the preparation of the sulphur autumn run using protons and oxygen ions.

The composition of the PS supercycle was frequently changed in order to introduce special cycles for accelerator studies in parallel with normal physics cycles or, to permit a faster filling of the AAC with three antiproton production cycles, especially when the SPS-LEP were not requesting lepton beams. In parallel, irradiation tests were carried out on various LHC equipment in the EPA and in the AAC target area. The East Hall regularly received 400 ms spills of 2×10^{11} protons per 14.4 s , shared between the 4 test lines. During two study periods of twelve hours, the PS Complex delivered protons to the SPS-LEP at 14 GeV/c in parallel with positrons for the LEP energy calibration. From the beginning of September, the lepton bunch length was increased from 3.3 ns to 4.3 ns. This improvement allowed intensities in SPS to reach 2×10^{10} leptons per bunch at 4 GeV, using the new SPS 100 MHz RF capture scheme.

On 24 September, the PS Complex commenced the fourth period with leptons for LEP, sulphur ions for the SPS and antiprotons for LEAR. After using protons at 20 GeV/c and O^{8+} ions for setting up the accelerators, the source was switched to sulphur ions on the 2nd October. Unfortunately, for the following 20 days the ion beams were seriously perturbed by major faults and the intensity delivered to SPS remained very low, of the order of 1×10^9 charges of S^{16+} sent in 4 batches per 19.9 s supercycle. Many factors contributed to this initially poor sulphur performance, namely a general cut of the 380 V in the PSB equipment building (13-hours), frequent source instabilities, vacuum leak in TT2 transfer line, problems on a pickup used for the PS beam control and a short circuit between two windings in the ion source which needed an interruption of two days to repair and re-condition the source. After the latter, the ion source worked extremely well with reasonable stability and the beams were transmitted with good efficiencies through the PSB and the PS. During a stable period of three weeks, the PS Complex regularly delivered an average intensity of 8×10^9 charges (5×10^8 ions) per supercycle i.e., more than a factor of two improvement over the previous best performance at the end of August 1990. During this period, LEP benefitted with an excellent availability of leptons from the PS Complex; the overall lepton fault rate was down to only 7.59%, a record for the year. LEAR continued to work with the antiprotons for various experiments i.e., CP violation and Crystal Barrel (200 MeV/c), Antiproton Trap, Helium Trap and Obelix (105 MeV/c) and Jetset (800 to 1500 MeV/c). A record of 3×10^{10} antiprotons were accelerated and stored in LEAR at 1480 MeV/c. Unfortunately, LEAR physics had to be stopped three days earlier in order to allow the repair of the 4-8 GHz stochastic cooling pick-up in the AA ring, so as to be ready in time for the last joint run devoted to the SPS Collider and LEAR physics.

The fifth period started well for proton beams but a serious problem occurred during the first weekend on a bending magnet in the AAC target area and delayed the antiproton production operation by six days. The operations to remove and replace this magnet were very delicate due to the high level of radioactivity in this area. Nevertheless, numerous preparatory adjustments were carried out in all the accelerators with proton beams; this resulted in very successful antiproton transfer operations a weekend later, with overall efficiency of ~ 95 % from the AA to the PS extraction at 26 GeV/c. During this run, the SPS Collider operated in the mode with 3 bunches of 6×10^{10} protons colliding against 3 bunches of 6×10^{10} antiprotons. This mode of operation and intensities had not been carried out since the debut of ACOL. SPS suffered from five energy-shedding 'critical' days and during these, the AA stack reached a total of 10^{12} antiprotons, a record obtained for the first time with the magnetic horn used as a collecting lens. However, the AAC Complex was again affected by a major problem; on 8 December the pulsed power stripline used by the magnetic horn exploded, causing a further interruption of five days in order to remove the horn and replace it by the 20 mm Li lens. The SPS did not suffer too much from this intervention because it occurred during three consecutive 'critical' days. During this run, LEAR was successively fed with protons for the the antiproton mass experiment (at 61.2 MeV/c), antiprotons for Crystal-Barrel (1.2 GeV/c) and the Hyperons experiment (1.95 GeV/c). On 11 December a new success was recorded i.e, for the first time a proton beam was extracted from the Booster towards the new 1 GeV transfer line up to the future ISOLDE target location, opening up yet another new user facility supplied with beams from the PS Complex.

3. LEP Pre-Injector (LPI) - Lepton Linacs and Accumulator EPA

In order to improve the reliability and maintainability of the LEP Preinjector (LPI), a new front-end of the Linac (LIL) has been designed and installed, taking advantage of the LEP shutdown in autumn 1990. It consists of a new electron gun pulser, a bunching system and a beam matching line bringing the beam up for the first LIL accelerating section. During commissioning in the late 1990 and routine operation since March 1991, the front-end has shown excellent performance and reliability. In the framework of LPI consolidation, a spare of the electron gun and its modulator have been built and installed on a test stand for precise beam measurements; a spare of the bunching system has been manufactured in collaboration with LAL, Orsay (France).

Since the start-up in March 1991, the LPI has served as an injector for LEP with an availability of 92%. The main problem in operation comes from the aging of LIL klystrons; these are being progressively replaced after a working life of over 18000 hours. The operating conditions and the interlock systems of these klystrons have been reviewed with specialists from industry and several European and American physics institutes during a meeting dedicated to this subject. The setting up of a klystron modulator test stand has commenced; this will facilitate component and interlock tests, circuit maintenance and development as well the RF conditioning of new klystrons and LIPS (LEP Injector Power Savers). During November, two major defects have been observed in the EPA ring i.e., a hidden defect in the wedging and welding of all bending magnet coils and corrosion in the vacuum feedthrough of the ion clearing electrodes. Both systems had to be entirely dismantled and this task was already started during the winter shutdown of the machines at the end of 1991. Certain other upgrades or feasibility tests were also carried out, particularly for the power converter of the test modulator as well as for the LIL solenoid.

A test area has been set up for the irradiation of the LHC sample vacuum and cryogenic equipment using the synchrotron radiation produced in the Electron Positron Accumulator (EPA). This is within the scope of the development work for the LHC because it has been shown that the synchrotron radiation spectrum of electrons in the EPA at 345 MeV is very close to the one expected for protons at 8 TeV in the LHC. It should be noted that the operational energy value for the EPA as part of the LEP injector chain is 500 MeV; similar tests for the SSC, if they were to be carried out at CERN, would necessitate an increase to 568 MeV. Irradiation of the LHC vacuum chamber samples have allowed the measurement of desorption parameters which differ substantially from the hitherto assumed values. These tests for the LHC will continue in 1992.

4. Hadron Injectors - Sources, Linacs and Booster

The Hadron Linacs have been working with their usual reliability. Highlights were certainly the successful sulphur ion run (resulting in the highest sulphur currents ever seen from the source ~ 25 mA) and the delivery of high intensity beams from Linac2 to allow LHC beam studies in the PSB. Another important change has been the replacement of BHZ20 by a pulsed magnet.This makes it possible to dump unwanted Linac pulses in a proper beam dump rather than in the measurement beam line, avoiding unnecessary radiation. It also allows the regular pulsing of Linac2 even though the beam line towards the PSB is already in use by the ions.

Despite the early start-up for the sulphur run, preparations of the source were plagued by persistent high voltage problems eventually traced to a contaminated extraction system. When the source was finally operational, acute instabilities made optimisation difficult. Poor performance was registered until a solenoid coil went down on an earth fault. Thanks to a concerted effort, the coil insulation was renewed within 48 hours and reconditioning could start again. This time the source behavior was considerably more stable and it was soon providing sulphur ions to the SPS. The accelerated beams were typically of the order of 6×10^8 ions per supercycle. As well as providing ions, Linac1 was again called upon to provide proton test beams for LEAR.

Planning has continued for the eventual replacement of the 750 kV Cockroft-Walton injector by the high intensity RFQ2 in 1993. Two RFQ's are planned, with one installed at Linac2 and the other serving as a spare as well as for the various tests in the experimental area. The RFQ2a has undergone extensive beam measurements and shown remarkable results, accelerating up to 250 mA of protons with adequately small transverse and longitudinal emittances. With more than 3000 hours of operation and 400 hours with full intensity beam, it has proved to be reliable with less than one missing pulse per day.

This has been due to better vacuum conditions. The RFQ2b, essentially identical to RFQ2a, is under construction in the CERN central workshop and is scheduled for beam tests in the early half of summer 1992.

At Linac2, protons have been provided for the PS Booster with special requirements for the high intensity, LHC type test beams. The source extraction aperture was enlarged to make source operation more flexible and towards the end of the year, argon was added to the normal hydrogen. This had a beneficial effect of a small increase in beam intensity whilst dramatically reducing the gas flow. These tests will be continued to discover the optimal argon contamination (<0.5%) .

The PSB has continued to deliver the various proton beams including the ones used for antiproton and collider operations. Some of these require permanent surveillance and care for reliable operation. In addition, new activities have commenced, particularly the installation of a 100 m long 1 GeV beam transport line towards the new ISOLDE facility. This work included the diagnostics and controls facilities and was completed within a very tight schedule, culminating in the successful delivery of $2x10^{13}$ protons/pulse to the dump on 11 December. A test beam matching the specifications for the future LHC injection scheme has been accelerated in the PSB with the Linac2 tuned so as to a produce a short, high-intensity pulse. Equipment to measure emittances of such small high-brilliance beams have been thoroughly reviewed and improved. The PSB acceleration of sulphur/oxygen ions succeeded in transferring to the PS intensities higher than ever before, thanks to improved source performance and extended beam diagnostics. The new thin-wire sem-grids installed in the PSB injection line are sensitive enough to measure weak ion beams as well as sufficiently non-destructive to be left in position for the intense proton beams.

5. Antiproton Accumulator Complex - AAC

The AAC commenced the year's operation with tests of a prototype plasma lens to collect the antiprotons from the production target. This resulted in some very encouraging results with yields of over $60x10^{-7}$ antiprotons per incident proton, as seen on the injection orbit of the Collector Ring AC. These yields compare well with yields obtained normally with a 400 kA magnetic horn and the 20 mm lithium lens. It should be recalled that the project to study and develop this prototype plasma lens was launched with the financial support from the German government and in collaboration with the University of Erlangen, Germany. Success of these plasma lens tests augurs well for the future tests planned in 1992. For the physics debut after a period of machine experiments, the AAC commenced with the classical 20 mm Li lens as the collector lens; however a serious fault after the first few days of running meant that a back-up solution using a 400 kA magnetic horn had to be brought into operation, with reduced yields. With over 5500 hours of scheduled physics running time foreseen for 1991, the AAC continued with this magnetic horn , including for the dual-client (LEAR & SPS Collider) run at the end of the year. The physics runs for LEAR till November were fairly stable with consolidated operation and a large number of economy hours (2469 hours) realized.These hours produce considerable energy savings because the AAC simply supplies beam to LEAR from a large, pre-accumulated stack, without recourse to continuous replenishment. For the SPS Collider run, the expected performance was reached in a relatively short time despite the gap of nearly one year since such peak performance was achieved previously.

Two major faults were experienced during the dual-client (LEAR/Collider) run at the end of the year. The highly radioactive bending magnet BHZ6024 broke down in mid-November and had to be repaired in a crash programme involving teams and remote-handling equipment from various divisions; in early December, the 400 kA horn and its stripline broke down, again involving considerable effort in manpower and equipment. Despite the radioactive nature and location of these faults, the repair work was achieved in record time with little consequence to the overall physics programme at LEAR or the SPS Collider.

6. Main Proton Synchrotron

Octant 2 of the PS ring was the last one to be renovated during the winter shut-down.With this completed, the whole of the PS ring has been rid of old equipment and unused cables; pipes, walls and floor have also been repainted. Some other systems have been entirely rebuilt or upgraded e.g., the power distribution, cooling & ventilation, fire detection and parts of the slow extraction beam line. Replacement of the water distribution system on half of the PS ring has been completed, the second half being left for the next winter shut-down. Work was also started for the cleaning and painting of the TT2 and the TT70 beam transport channels. Two new septa, outside vacuum, were constructed for the new Slow Extraction scheme and await installation in straight section 61 in early 1992. The third one, under vacuum, was also constructed and will be installed in straight section 57. Most of this work for the new Slow Extraction scheme has been achieved during the 1991 long shut-down and the power converters necessary for this have also been upgraded. As far as the RF equipment is concerned, upgrading of most of the ferrite cavities took place during the shut-downs; all these efforts in improvements of the 114 MHz systems paid off handsomely in the form of increased reliability of lepton beams throughout the year. A programme for the renovation of the main generator has been started. Specifications, calls for tender and allocation of orders have been defined for the motor generator and for part of the generator excitation. Renovation of the pulsed power supplies for the PS fast extraction system has also commenced.

For the beam diagnostic equipment, a new, short wall current monitor(bandwidth: 3 GHz) has been developed and installed in the PS ring and has produced good results with proton beams. A development programme for the fast wire scanners has been launched with a unit available for laboratory tests and another on order for operational use. The sem-grids in TT2 have had their sensitivities improved to permit measurement of ion beams.

Beam studies have been mainly related to the theoretical and experimental aspects of the proton beam in the PS complex in order to cope with the LHC requirements. The lepton bunch length at 3.5 GeV was increased to 4.3 ns to match to the new SPS requirement. Studies of the transverse collective effects due to trapped ions in the electron beams were carried out as well as studies related to the future acceleration of lead ions in the PS complex.

Concerning outside collaborations, two magnetic septa and kicker magnets were delivered to the European Synchrotron Radiation Facility (ESRF), as well as magnetic septa for KFA in Jüllich.

7. Low Energy Antiproton Ring - LEAR

The jet set experiment had its first long running period in 1991 at momenta between 609 and 2000 MeV/c, with circulating beams of up to 3×10^{10} antiprotons. To maintain these beams within good emittances and momentum spread by stochastic cooling, wide band amplifiers (10 W, 1 GHz) have been successfully installed and used. Emittances of less than $2\,\pi$ mm.mrad have been measured with the jet on. Luminosities of 6×10^{29} cm^{-2} s^{-1} have been achieved with a jet density of 6.10^{12} $atoms.cm^{-2}$. This density is limited for the time being by the geometry between the jet source and the jet recovery system.

Ultra slow extraction is now possible for momenta between 61.2 and 1980 MeV/c. Particle fluxes of more than 2.10^{6} s^{-1} at 309 MeV/c and 10^{6} s^{-1} at 200 MeV/c have been achieved for spills of at least 1 hour. Overall extraction efficiency is better than 70% with a duty factor (ripple) of 95%. For the low energy beams (mainly 105 and 61.2 MeV/c) electron-cooling was used routinely in operation. Better deceleration, beam characteristics and life time were observed at these low energies. The trap and the spectrometer experiments (PS196, PS189) have greatly benefitted from this type of operation.

To keep the high density beam stable, an elegant transverse active feedback system is routinely used. This system works for all momenta despite the large revolution frequency swing (0.25 to 3.5 MHz).

In 1991, the main improvement was achieved at 61.2 MeV/c with the slow extraction technique being used for the first time in routine operation (experiment PS189). The extraction process is completed in 500 μs, the time window corresponding to the pulse length of the RFQ post decelerator (61.2 to 20 MeV/c). During a fortnight of trials, a relatively fast progress was made on the quality of this extracted beam and the subsequent deceleration in the RFQ, using protons instead of antiprotons. This was principally due to the use of the electron cooler to speed-up the deceleration cycle and the continuous availability of protons from the Linac1.

8. Experimental Areas and ISOLDE

East Area

Over the 26 weeks during which the beam was delivered to this area, 25 different groups of users took data using the four test beams; these ranged for periods of one day to a few weeks. These tests have been devoted to research and development, improvement and calibration of detector components (scintillators, semi-conductors, calorimeters, Cerenkov counters, etc.). Slow Extraction spills of a beam with strong RF structure have also been performed to simulate the use of detectors with multiple bunches in future colliders. An upgrade programme for this area has been launched. It consists of the implementation of new computer controls for the power supplies driving the beam line elements, an up-to-date read-out system for the Multi Wire Proportional Chambers, an upgrading of the splitter magnets and a general cleaning up of the area.

South Area

The 9 experiments of this area received proton or antiproton beams for 4200 hours in 1991. Antiproton beams constituted 92 % of the total physics time. As in previous years, several modifications were carried out to improve beam quality or to cope with the users' requirements. Most of the efforts were dedicated to the low energy lines (momentum < 105 MeV/c). For the first time, protons and antiprotons were decelerated down to 61.3 MeV/c in the line S3. Experiment PS189 successfully commissioned the newly installed RFQ in this line and decelerated protons down to the energy of 200 KeV. Following these results, data taking by this experiment should take place in 1992.

An algorithm for beam steering has been put into operation, using quadrupoles as position monitors. This permitted the experiment PS195 on beam line S1 to take data with the same beam angle and position irrespective of the solenoid polarity. This method will now be used on the other beam lines.

Transfer line interconnections have been modified in this area to extend the number of possible sharing configurations between the different experiments. New lines , called X lines, have been subsequently installed.

To observe the position and profile of very low energy antiproton beams, three systems of position-sensitive photomultipliers coupled to thin inorganic scintillators have been installed. In the same vein and for experiment PS189, three systems with CCD cameras directed at ZnS screens have been installed.

ISOLDE

The project of moving the ISOLDE activities to the vicinity of the PS Booster has progressed as scheduled. All surface buildings have been constructed this year including the experimental hall, access area and ancillary buildings. The main technical services like the power distribution, heating, ventilation and cooling have also been installed. Elements of the 1 GeV proton beam line from the PSB to the future targets have been delivered and installed, as well as power converters and associated elements (beam loss monitors, scintillation screens, beam current transformers, vacuum and mechanical components etc). Developments were also carried out on the 60 kV pulser for the target. Moreover, specifications and calls for tender have been issued for the quadrupole power converters; this is in order to permit the shared beam operation between the PSB measurement line and the ISOLDE in the future. On the 11th of December, a beam from the PSB was transported for the first time to the target gallery i.e., to the place where the future target will be positioned to feed the General Purpose Separator (GPS). This success opens the way to the future ISOLDE physics programme which should be in operation by the late spring of 1992.

9. Computer Controls and Office systems

Controls activities during 1991 have been dominated by the first slice of the joint PS/SL control consolidation project D067, namely the rejuvenation of the controls for the LPI. In addition, the servicing and exploitation of the running control system constituted a major part of the ongoing activities, often under strained circumstances due to lack of sufficient staff for on-call duties.

The major modification to the existing control system (the Norsk Data System) was the addition of controls for the CTF equipment to the LIL front-end computer as well as the control of the beam transfer line from the Booster to the ISOLDE target on the Booster front-end computer.These facilities were put into routine operation for the CTF as well as for the PSB-ISOLDE transfer line tests at the end of the year.

The operation of the PS Local Area Network (LAN) with its large number of equipment connections for controls, office automation and remote access to the CERN central computing facilities has been increasingly complicated. A split of this network has been carried out by dividing it in two isolated segments i.e., for offices and for controls. These segments are connected by a fast gateway; this provides the necessary independence of the accelerator control system from the rest of the CERN LAN by filtering the various communications.

For the the first slice of the consolidation project D067, a technical proposal was finalized by the PS and SL teams at the beginning of the year. The introduction of a "Real Time UNIX" operating system for the equipment front- end processor (the Device Stub Controller, so called DSC) was the last major decision taken, providing a uniform system and environment for front-end services, workstations and permitting the use of PC hardware where appropriate to complement the VME-based systems. The emergence of POSIX compliant operating systems was the main turning point for this choice. After calls for tender, the Lynx-OS system was selected for both the VME and the PC platforms. Version 2 of the Lynx-OS has been installed at the end of the year and has shown sufficient robustness and reliability to be implemented for routine operation for the beginning of 1992. A diskless version, bootable across the TCP/IP network, has been set up and provides through the NFS file system all the requested services for equipment front-end controls.

On the workstation side, the console manager and generic applications have been developed and put into operation. The generic programs include individual equipment control panel, equipment parameters display, error-logging and display and the first version of the alarms panel. The other major service is the uniform and transparent equipment access to the three classes of control networks in the PS complex i.e., the Norsk Data system, the DEC RSX Linac system and the new RT UNIX DSC architecture. The

Nodal interpreter has been enriched with an emulator of the old NORD-console environment in order to re-use, with a minimum of modification, the Nodal programs of the old control system.

The general services have been regularly enriched with the installation of selected software packages for the SASD, user interface builder, symbolic computation, spread-sheet, network management and data base. For the data base service, the common PS/SL data base computer and its back-up have been installed and put in use with version 6 of the ORACLE database. The performance of this service has been very encouraging for the use of an online relational data base management system in controls. For the fast real-time and read-only data, a service built on a standard UNIX platform has been developed and provides all the necessary tools to down load the data from the ORACLE database .

The basic infrastructure of the application programs has been ported into the Lynx-OS DSC; the different methods managing external timing events and providing the inter-process communications have been studied, implemented and the response time measured. A software production-line has been set up and validated. All the equipment modules and their associated real-time tasks for the PPM (Pulse to Pulse Modulation) based equipment have been built with the help of a software firm under contract.

On the hardware side, the development of the new high performance general function generator (GFAD) has been completed. This includes the embedded software of this module. The CAMAC serial driver in VME has been produced by industry; the associated Lynx-OS driver with full LAM handling capability has been completed and extensively used for the LPI controls consolidation. A VME module to receive the PLS telegram was designed and is expected to be under series production in 1992. A new generation of the timing and PLS receiver (TG8) module has also been specified and designed in collaboration with the SL Division; this will provide a uniform timing system for all of the CERN accelerators. For the LPI controls, 13 VME crates with processor and service modules (the DSC set-up) have been installed and the CAMAC crates connected to them. This environment has been successfully put into operation during the LPI test period in November. During these two weeks scheduled at the end of the LEP physics run in 1991, the control system of the LPI was disconnected from the Norsk Data/SMACC environment and converted to the the new UNIX/DSC architecture. This period concluded with the full beam production by the LIL Linacs running under the new controls environment. The test exposed some reliability and response time problems and a correction plan was defined and implemented to provide an operational situation for the 1992 LPI start-up.

The PS expert system development environment has moved to the SUN UNIX workstations, providing better integration into the new controls architecture. For the ESPRIT-II ARCHON project, these facilities have been successfully used to run the cooperation layer GRATE across a network with real agents on the different workstations and environments.

Standardization and convergence activities in the field of protocol for equipment access has continued in two different areas. A CERN wide working group (USAP) to define a unified software access procedure has been set up and its final conclusions are expected for the middle of 1992. Prototypes of the control protocol for beam instrumentation have been developed in the context of the LPI controls consolidation and other developments for power converters and vacuum systems are in the final definition phase, with prototypes expected in 1992.

The second year of collaboration with IHEP-Protvino (ex-USSR) for the control system of the UNK project has been dominated by the full and detailed design of the control system. This has been done by an IHEP team at CERN, in conjunction with CERN staff. Two pilot projects have been defined, (a) the control of the 70 GeV injection line which uses the industrial control shell connected to the low-level controls facility in development at IHEP and (b) a full vertical controls slice, using the modern "standard controls architecture", as defined at CERN. These pilot projects are expected to be put into operation in 1992 at Protvino. This collaboration shows promise and is rewarding for both parties.

Informatics and Office Systems

The Division's informatics and office network has continued to thrive with substantial services provided to users, even outside the Division. On average , over 200 logged-on users during the day is common, with over 300 log-ins daily. Major effort has been carried out for the integration of different platforms of computers, operating systems and services existing in the Division. Notably, the network printers are accessible from the PCs, Macintoshes, UNIX workstations as well as central computers (e.g., IBM CERNVM) in their native modes; except for the latter , the file system is also sharable, permitting transparent exchange of information. Support and recommended use of standard tools for spreadsheet (MS-EXCEL) and word processing (MS-WORD) applications has continued while support of the CAD and engineering tools on the network has now been centralised in the CN Division.

10. Research, Development & Projects

Lead Ion Accelerating Facility

The year 1991 has seen decisions taken by CERN and the collaborating institutes on the major systems of the heavy ion (lead) Linac. In particular, the IH structure was chosen for the ion acceleration between 0.25 MeV/u and 4.2 MeV/u after the successful commissioning of a very similar structure (0.3 MeV/u to.4 MeV/u) at GSI. With these decisions taken, it was possible to establish a construction schedule aiming for heavy ion physics in the second half of 1994.

The main parts of the lead ion Linac and its rf system are being provided by the collaborating institutions (mentioned below) with CERN taking care of the overall coordination, the buildings and infrastructure (services), as well as the controls system. The following summarizes the status at the end of 1991:

The ECR Ion Source for lead ions is being built and tested at GANIL. Beam currents of 80 μAe of Pb^{28+} have been measured on the test bench.Beam transport elements between the ECR source and the RFQ have been designed and specified by IFN Legnaro for fabrication. The choice of the RFQ structure for accelerating from 2.5 keV/u to 250 keV/u is being based on thorough assessments of rf and mechanical aspects. Beam transport elements between RFQ and IH Linac which have to fulfill strict matching requirements, have been defined.For the acceleration between 0.25 MeV/u and 4..2 MeV/u, IH cavity, drift tube lengths, and focusing parameters have been defined by GSI via detailed dynamics computations and the mechanical design is well underway. RF power requirements have been evaluated for the two bunchers, RFQ, the IH tank1 at 101.28 MHz and for the IH tanks 2 and 3 at 202.56 MHz. Detailed specifications are in preparation at GSI. Beam transport elements and beam monitoring equipment which are used in the charge stripping and charge-state filtering line at 4.2 MeV/u have been designed and ordered through the collaboration of CERN and Turin University. In addition, controls software is being developed in collaboration with a team from several institutes in India and extra financial support is being given by Sweden and Switzerland.

At CERN, the preparations for the dismantling of Linac1 are well underway, with the last operation of the latter in the CERN Accelerator Complex scheduled for the first week of June 1992. It is expected to have the building emptied of Linac1, modifications carried out and then equipped for the reception of the lead Linac components before the end of 1992. During the course of 1991, design studies including the mechanical engineering solutions for an alternative design of the lead Linac using the Quasi-Alvarez structure were completed.

Computational methods used on the latter structure have been extended for studies on the IH structure, both for the cavity calculations (MAFIA) as well as for the beam dynamics, including the rf field tolerances. Work on voltage breakdown using nanosecond pulses has demonstrated that the electric fields of 500 MV/m could be held across gaps of about 20 mm in vacuum.

Laser Ion Source Studies

Laser ion source studies have continued with the help of Russian collaborators. Plasma densities of highly charged lead ions have been measured. These studies have gained additional interest because they open up the possibility of producing very short pulses suitable for monoturn injection into the Booster. This process would result in very low beam emittances leading to high luminosities in the LHC without recourse to any intermediate stochastic or electron cooling. However, problems of high space charge effects after extraction still need further investigation.

LHC Implications for the PS Complex

The PS Complex, the source of all particles in CERN, will be the natural "pre-injector" for the LHC. Beams of very high transverse densities are required to insure a lossless beam injection into the tiny aperture of the LHC magnets as well as to achieve the design luminosity at collision. The design goals and main features of the LHC proton injector chain (RFQ2 - Linac2 - PSB - PS - SPS) were thoroughly discussed earlier in the year and hardware additions for upgrading the performance of the chain were proposed (see The Design Study of the LHC , CERN 91-03). The characteristics of the beam required for extraction from the PS are: (a) 1.4×10^{13} protons per cycle, (b) 140 bunches of 9 ns length each, 15 ns spacing and, (c) normalised r.m.s. emittance of 3.0 μm.

This beam, with twice the transverse density over today's performance, could be attained after the addition of following hardware : (a) a 200 mA proton RFQ (b) two new RF systems in each of the four PSB rings, working on harmonic one and two respectively of the revolution frequency (c) increase of the PSB output energy from 1 to 1.4 GeV to reduce the space charge effects in the PS (d) double-pulsing of the PSB for one PS filling to minimise the space charge effects in the PSB and lastly ,(d) a 66 MHz system RF system in the PS to finally deliver 140 bunches at 26 GeV/c towards the SPS.

The high intensity RFQ has indeed accelerated some 250 mA on its test stand and will replace the 750 keV Cockcroft-Walton pre-accelerator in 1993. First attempts to produce the required beam density in the PSB have been very encouraging. Other machine development sessions dealt with the simulation and observation of this type of beam, looking at its behaviour on the PS flat bottom of the magnetic cycle, the passage through transition, and the debunching /rebunching procedure for forming the final bunch spacing at 26 GeV/c. Up to now, no insurmountable difficulties have been observed. Major efforts are being invested in the beam profile measurement devices along the chain; these would enable the very small-sized LHC-type beams to be properly measured.

The CERN Linear Collider Test Facility (CTF)

The CTF has been brought into operation in 1991. Initially, a prototype 3 GHz, 1 1/2 cell radiofrequency electron gun with a laser driven photocathode has been tested. The lifetime and efficiency of the photocathode (CsI with laser wavelength of 213 nm) has proved to be suitable for these tests.

The electron energy at the gun output has usually been limited to two-thirds of the design value (4 MeV) due to the voltage breakdowns in the gun. Trials with a newly constructed gun will be resumed in 1992. Using a spectrometer and a slit, a particular momentum bite of the beam from the gun is accelerated in a spare LIL section to 40 MeV.

The Nd:YAG laser, operating at wavelength of 213 nm, delivers 7 ns long pulses. Due to the bunching effect in the gun, the resulting beam consists of a train of 37 ps long micro bunches. The bunch train has been focussed through a CLIC prototype structure and the excited 30 GHz power measured. In 1992 it is foreseen to use a Nd:YLF laser (wavelength : 209 nm , 7 ps pulses) synchronized to the rf in the gun. In this mode, it is expected to produce bunches matched to 30 GHz power generation in the CLIC structures and to obtain power levels well above the maximum of 80 kW achieved so far. Using this method, a primary requirement is the creation of a train of laser pulses. Work on such a pulse train generator has progressed in 1991 but, with the wavelength of 209 nm, the solution is not readily found. Studies on the fabrication and performance of different photocathodes have also been pursued. It was found that Na2KSb cathodes provided good efficiencies but short lifetimes. A surface cleaning system using ion bombardment has been built with possible application for the use of metal cathodes. Using a streak camera, techniques have been developed to measure the bunch length; resolutions down to 2 ps for transition radiation and 3.4 ps with Cerenkov radiation have been obtained.

Beauty and τ-charm factories

The division has continued to participate in the design studies for the possible construction of B and τ-charm factories in Europe.

On the request of ECFA and following the preliminary design study of a B-factory made in 1990, a list of necessary R & D work towards a high luminosity asymmetric B-factory has been made and presented on various occasions in 1991. A conceptual study of a τ-charm laboratory to be constructed in Spain was also carried out at the request of the Spanish Authorities. This covered the construction plans for a two ring collider with an energy of up to 5 GeV in the center-of-mass, together with its electron and positron injector. The laboratory needs in civil engineering, infrastructure and general facilities have also been evaluated, together with cost estimates and manpower requirements. The study also included a construction schedule proposal.

SuperLEAR

After an interruption of several years, the studies for SuperLEAR which commenced initially in 1985-87 have been reactivated, involving several working groups of physicists and mainly driven by the needs of LEAR users. A working group for the future antiproton programme has been set up in the PS Division and operates in close contact with the physics community. Different possible developments are under study, identified after the meeting of the SPSLC held at Cogne in September 1990: (a) the future evolution of LEAR itself in two possible scenarios, namely the very low energy domain for antihydrogen production and storage, and the use of a medium energy, high luminosity (5.10^{31} cm^{-2} s^{-1}) internal jet target for CP violation studies through the lambda-lambdabar channel and (b) the design of a 12 GeV/c superconducting storage ring (superLEAR) to be installed in the PS East Hall for charmed meson and hybrid spectroscopy. A proposal on these lines, with two internal jet targets and an extraction facility for two external targets and experimental areas has been presented at the SuperLEAR Users Workshop held in Zürich in October 1991.

These studies continue and result from the evaluation of the user community requests. It is foreseen to make a presentation of this work at the SPSLC meeting in September 1992 at Cogne.

TABLE 1
Statistics of PS ring operation in 1991

Scheduled physics running time	5684h
Achieved physics running time	5439h
Scheduled setting-up time 1)	697h
Total ejected proton beam intensities :	
antiproton production	$1{,}80x10^{19}$
SPS collider	$1{,}16x10^{17}$
SPS fixed target	$2{,}87x10^{19}$
East Hall slow ejection	$2{,}73x10^{19}$
To beam dump	$0.44x10^{18}$
1) Includes some machine development	

TABLE 2
Statistics for AAC operation in 1991

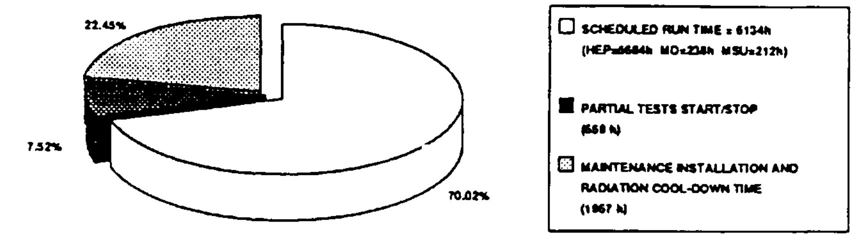
Scheduled physics running time	5544h
Achieved physics running time	5568h
Total number of antiprotons produced	$2{,}215x10^{13}$
Average production rate	$1{,}174x10^{10}/h$
Maximum stack during 1990	$1.093.10^{12}$
Total number of antiprotons sent to SPS	$6{,}873x10^{12}$
Total number of antiprotons sent to LEAR	$8{,}701x10^{12}$
Accidental stack losses	$6{,}576x10^{12}$

TABLE 3
Statistics for LEAR operation in 1991

Scheduled physics running time	4204 h
Scheduled setting-up time	1616 h
Achieved setting-up time 1)	1351 h
Total number of pulses injected	2633 h
Total number of pulses extracted for physics	2133
Total number of antiprotons injected	$6.3x10^{12}$
Total number of pbars ready for extraction for physics	$4.9x10^{12}$
1) Includes physics, setting-up and machine development	

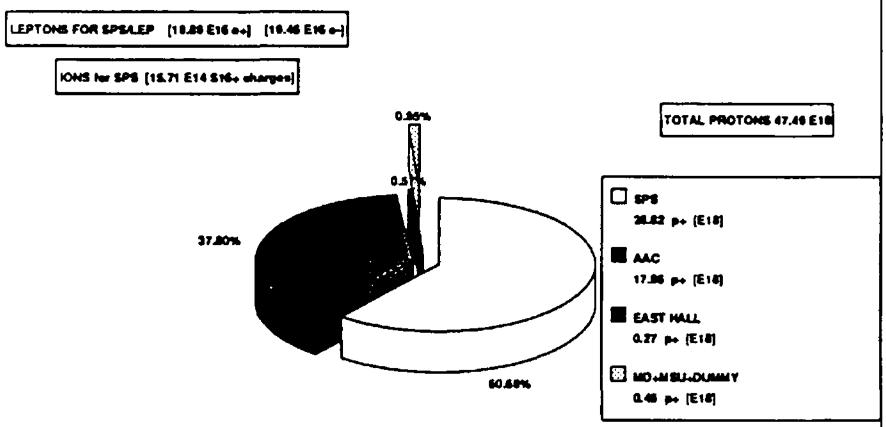
TABLE 4
Statistics for LEP pre-injector operation in 1991

Scheduled lepton production time	5531,5 h
Achieved lepton production time	5081,0 h
Scheduled production time for LEP (MD PS)	4973,5 h
Achieved production time for LEP	4550,0 h
Total number of electrons sent to SPS/LEP	$19.46x10^{16}$
Total number of positrons sent to SPS/LEP	$19.89x10^{16}$



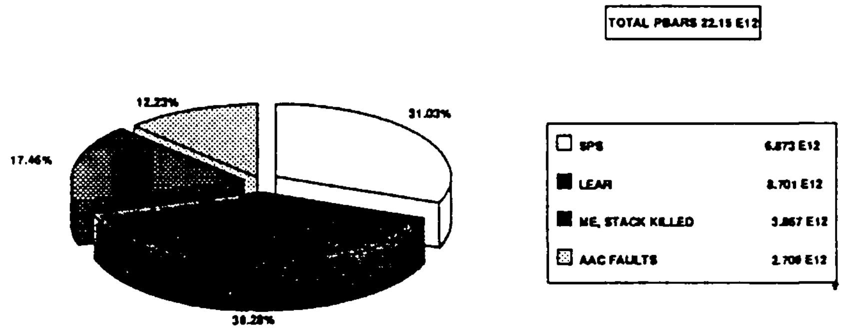
PS COMPLEX ACTIVITIES IN 1991

G.A.



GENERAL DISTRIBUTION OF PROTON, LEPTON AND ION BEAMS ACCELERATED BY THE PS IN 1991

G.A.



GENERAL DISTRIBUTION OF ANTIPROTONS SUPPLIED BY AAC IN 1991

G.A.

Fig. 1

PS COMPLEX ACCELERATORS: HIGHLIGHTS OF 1991

MACHINES		PEAK VALUES	NOMINAL VALUES
LIN1/PSB/PS LIN 1	Ions (Sulphur S16+ extracted from PS) O6+ intensity	1.1 E10 charges / supercycle (4.9 E9 in 1990) 300 microAmps.	7.5 E9 charges / supercycle (3 E9 in 1990) 100 microAmps.
LPI/PS	Lepton intensity	4 E10 e- per bunch at 3.5 GeV (MD)	2.5 E10 leptons / bunch (in operation) bunch length: 4.4 ns
AAC	AA intensity Particles stored per shot in AA	1 E12 pbars (with the magnetic horn) 5.7 E7 pbars/shot (with the magnetic horn)	
LEAR	the lowest pbar momentum at extraction the highest pbar momentum at extraction Intensity stored at 1480 MeV/c	61.2 MeV/c (2 MeV Kinetic) 1.992 GeV/c 3 E10 pbars	
LIN 2/PSB	First beam in ISOLDE transfer line on 11 December 1991	2 E13 protons/pulse	

Fig. 2

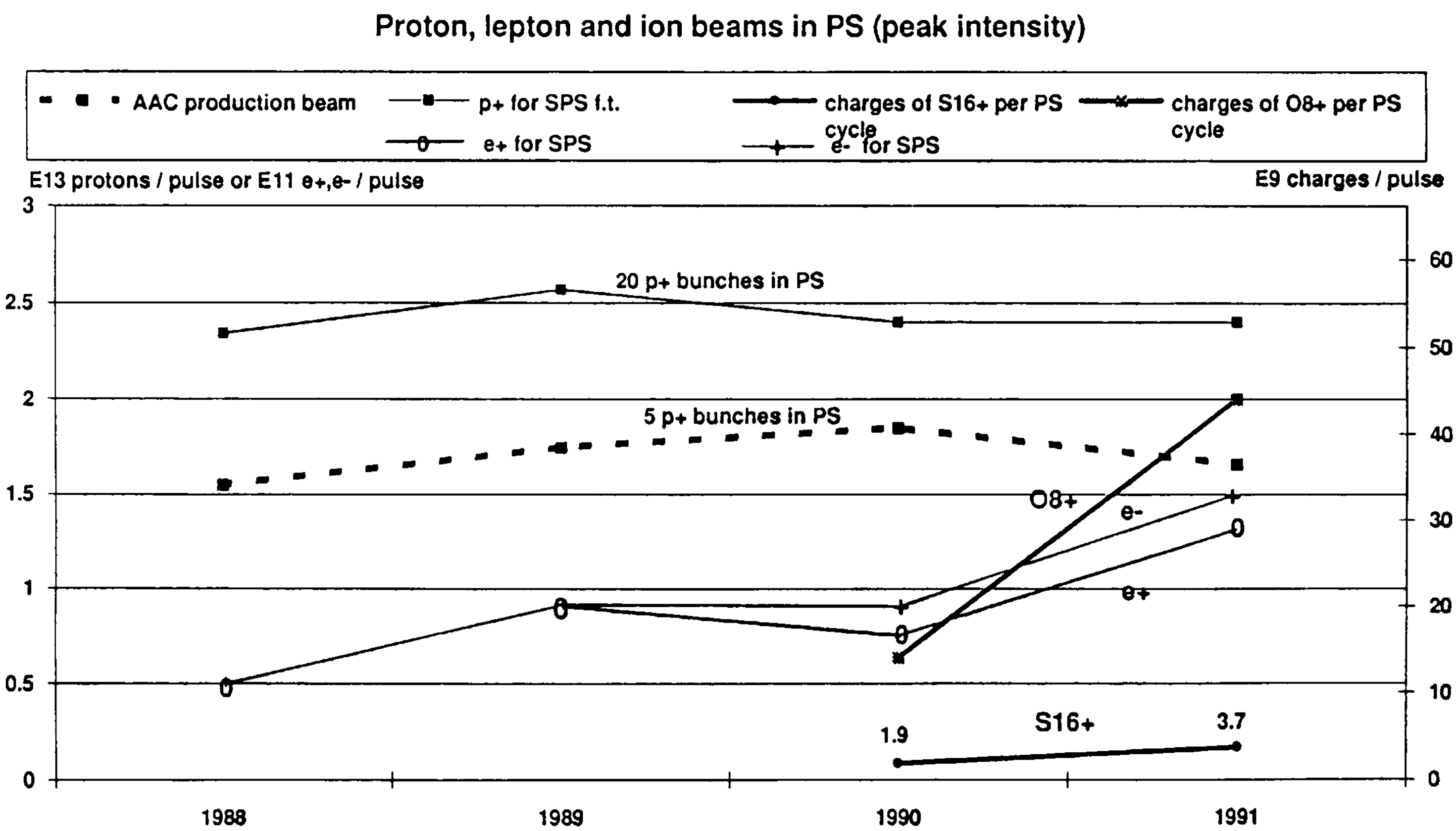


Fig. 3

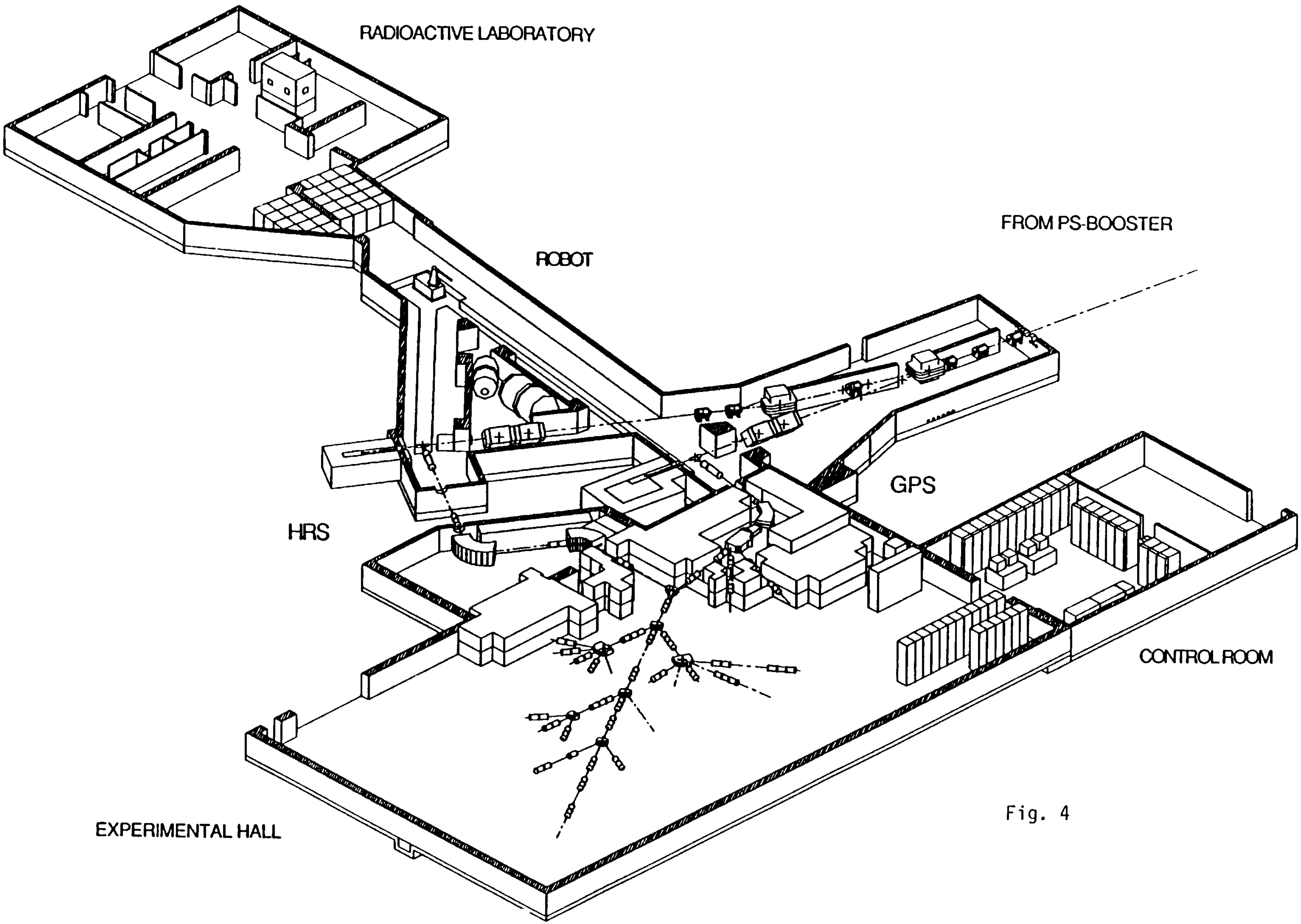

RADIOACTIVE LABORATORY
ROBOT
FROM PS-BOOSTER
GPS
HRS
CONTROL ROOM
EXPERIMENTAL HALL
D.PARCHET

Fig. 4