1. Introduction

This report summarises the five ISR physics running periods for 1983 which extended from run 1319 (22nd February) to run 1395 (23rd December 1983). A complete list of all 1983 runs with their main filling and physics parameters is attached.

Operation of the ISR started in the last week of February and was interrupted for two weeks in July and one week in September. An unforeseen stop of two weeks was needed in October (instead of one) for an urgent repair to a pylon of the 130 kW Verbois electricity line.

The physics demand for the last year of ISR colliding beam operations was very diversified. Energy running requirements were essentially at 31 GeV/c, with a few runs performed at 15, 22 and 26 GeV/c. Furthermore, a four week low momentum antiproton run (3.5 GeV/c, antiprotons in one ring against a hydrogen gas jet target) dedicated to experiment R704 was completed end of July. This was closely followed in August by a two week period of operation with alpha and deuteron particles with the anticipated top performances. At the end of the year, a 5-week p-p run with both the steel and SC low-β in operation was aborted (SPM cooling failure) after 3 weeks of successful data taking. As no anti-protons were available at the AA, a comparison run at 26 GeV/c and 4 31 GeV/c runs with protons were rescheduled. Run 1395 ended operation of the ISR as a beam collider. Next year a seven or twelve week running period, using low momentum anti-protons in ring 2, has still to be carried out for R704.

No major changes took place in the intersection regions. The current ISR experiments R110, R419-420, R608 and R807-808 continue data taking. R704, who completed their installation work in January, started data taking after initial tests. Experiment R421/422 had to be completely prepared with new detectors and R210 came back during a few runs for new measurements on p-p total cross section. Unfortunately, R110 lost considerable data taking time due to serious breakdowns of the cryogenics plant for the superconducting solenoid of that experiment.

2. Operations Review

2.1 Start-up and 31 GeV/c operation

After the winter shutdown, the ISR operated mostly at 31 GeV/c. In general the machine behaved rather well despite a number of breakdowns of various essential pieces of equipment, such as the inflector/shutter hydraulics, computer disc controllers, cooling system, power supply controls and the solenoid in I-1 which often failed.

Although the start-up went smoothly, the luminosity hoped for during high intensity runs was not obtained from the start. During many runs, unexplained beam blow-up occurred during beam centering and in several runs the first beam stacked suffered blow-up at the top when the second beam was
Accelerated. The resulting increase in $\text{heff}$ was not only due to these factors but also to a noticeable increase of the PS beam emittance. This problem, which affected all of the PS customers, was finally solved in the second half of the year. On the other hand, in order to meet the ejection requirements for the neutrino experiment which came into operation at the beginning of the year, the PS ejection for the ISR was tuned to take place on the flat top of the PS cycle instead of the rising edge. However, measurements of the PS beam emittance did not show significant differences between the two types of ejection.

Stacking and acceleration to 31 GeV/c followed the well established procedure on LB optics. Very few working line and closed orbit corrections were needed. For some runs stacking was perturbed by unexplained beam losses (transverse instability due to high density) and erratic timing synchronisation pulses which gave spurious triggers on the injection kicker.

Despite the lower initial luminosities obtained, the reliability of the machine components during stable beams was much better, permitting longer data taking, and hence the integrated luminosities per run were higher than in 1982 (of the order of 25%).

2.2 Special running

During the first running period, a 60-hour special high intensity run at 26 GeV/c took place with both the steel and the SC low-B in operation (DL optics) in I-1 and I-8.

To prevent quenches, very careful beam optimisation and collimator protection were needed during start-up and filling. The rematched DL scheme with the working line placed above the diagonal ($Q_H = Q_Y$) tested last year gave good results. With currents of about 30 Amps in both rings, an initial luminosity of $1.3 \times 10^{32} \text{cm}^{-2}\text{s}^{-1}$ could be obtained in I-8 with rather good background conditions.

After initial computer file testing, the special runs at 26 and 31 GeV/c for experiment R210 with low currents and Tervilliger scheme in operation resumed satisfactorily. Moreover, meeting the physics demand, two high intensity runs at 15 GeV/c (1343-1381) and one at 22 GeV/c (1356) were also completed with no major difficulties. The peak currents attained at 15 GeV/c and 22 GeV/c were about 20 and 29 Amps respectively.

2.3 Low momentum running (R-704)

The installation work for the gas jet target experiment R704 was completed in January. Initial equipment testing using a controlled "residual" gas pressure bump in I-7 during normal runs was tried and gave good results.

To optimise further the delicate equipment and to finalise the operational machine procedures, a week's running with low momentum protons at 3.5 GeV/c took place at the end of March. During the second week in May after the R1 beam pipe had been removed, the first physics run with low momentum antiprotons (run 1346) proceeded on the whole very successfully despite the modest $p^-$ current obtained (350\muA). The pulse was phase displaced and cooled to the right momentum for physics data taking (between 3.6 and 6.4 GeV/c).
The momentum cooling used for compensating the energy loss due to the passage in the hydrogen jet and for reducing the momentum spread of the beam, worked better than expected. Likewise, the vertical cooling system used to counteract the vertical beam blow-up caused by the gas jet, operated throughout the run without any problems.

In mid-July, a further four weeks of special running with antiprotons (runs 1363-1366) were completed successfully. A p^- transfer was scheduled at the start of each week and was followed by four days of data taking. Weekends were reserved for vacuum interventions on the jet cryo-system. During that period, four antiproton transfers to ISR gave some difficulties with unexplained large particle losses between the PS ejection and TT6 transfer line. The transfer efficiency AA-PS-ISR never exceeded 70%. With a p^- peak current of the order of 3mA, the recorded luminosity with the gas jet in operation reached $1.6 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$. The decay rate for R2 stabilised around 100 ppm/min and was dependent on the gas jet pressure. The last run was unfortunately curtailed by more than 24 hours due to an 18 kV network breakdown.

2.4 Alpha and Deuteron running

In mid August two weeks of special running were devoted to alpha-proton-deuteron running (runs 1368-1370). On the PS complex side, the preparation for d and alpha extraction and acceleration was very promising. An important improvement in intensity was expected (use of the booster) compared with similar runs performed in 1976 (deuterons) and 1980 (alpha-alpha, alpha-proton). Normal LB optics were used for 26 GeV/c (alpha-alpha, d-d) and 22 GeV/c (alpha-proton) runs and the acceleration to 31 GeV/c (alpha-alpha) followed the usual phase displacement procedure. For all the runs, after some changes in the timing synchronisation pulses and RF parameters, the machine behaved very well. Unfortunately, scheduled in the summer period, almost every run was aborted due to beam losses caused by thunderstorms. Furthermore, during two runs (1369-1370) a serious breakdown on the hydraulic/mechanical part of both shutters of the injection kicker limited the amount of current stacked. For the first alpha-alpha run, a record current of 12.8 Amps of alphas could be stacked. The remaining current at 31 GeV/c was about 11 Amps.

With an initial luminosity in I-5 of $0.4 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, the working conditions were reported as very good by the physicists. Likewise, the deuteron run at 31 GeV/c (run 1370) operated with a record current of 19.5 Amps and a luminosity of $4.7 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$. Scheduled to last for more than 100 hours, this last run ended the period prematurely after 28 hours of data taking when both beams were lost due to an OAFM interlock chain failure.

2.5 High intensity $p^-p$ running

The last ISR running period was essentially devoted to 5 weeks of high intensity $p^-p$ operation at 26 GeV/c using the double low-$
\phi$ (DL) optics.

After a comparison run with protons, the start-up of the $p^-p$ run (1390) was delayed due to a serious fault on the SFM power supply. The $p^-$ beam was stacked first and ended up with a current of 6.7 mA $p^-$. The transfer efficiency was very good. Stacking for the proton beam gave no major problems and usual care was taken to avoid quenches in the SC magnets. In
order to ensure good physics working conditions, the R1 proton current was limited to 15 Amps. Initial background in the intersections was reasonably good but I-2 and I-1 were difficult to satisfy. The problem seemed to come from the large vertical bump needed to bring the beams into collision in I-1 when the solenoid is in operation and which leads to a restricted vertical aperture in the intersection.

The optimum period for a proton refill in R1 was about 2 or 3 days. Indeed, with DL optics, the proton beam seemed to blow up quite rapidly and frequent clean-ups were necessary to maintain good background, thereby reducing the luminosity. Over a 5-day period 13.8 mA of anti-protons were accumulated in Ring 2 from 3 AA stack transfers, whereas in Ring 1 the proton beam was renewed 6 times, the current being gradually increased to 20 Amps. The record luminosity obtained in I-8 (with the SC low-8) was of the order of $4.5 \times 10^{28} \text{cm}^{-2}\text{s}^{-1}$.

During the preparation of the 7th renewal of R1, the antiproton beam (13.05mA) was lost due to a SFM power supply failure. At that time the first p- stack had been circulating for just under 15 days. Both rings were again prepared for filling and the AA transfer ended up with a stack of 7.9 mA p-. With a proton current of 19 Amps the background conditions were similar to those of previous stacks. A second AA stack transfer brought the current in R2 up to 13.35 mA and R1 was renewed with 21 Amp protons. Unfortunately, after 40 hours of running, both beams were again lost due to a SFM water cooling failure.

As no refill with antiprotons was possible, R2 was reconverted for proton running and a second comparison run with DL optics took place for 32 hours. Later 4 runs at 31 GeV/c were rescheduled until the end of the period (23rd December, 1983).

Run 1395 ended the history of the ISR as a colliding beam facility.

3. **Statistics**

The main physics parameters are reviewed in tables 1 and 2.

The total stable beam time and the total integrated luminosity measured in I-5 are given in the following table.
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The total integrated luminosity and the total hours dedicated to data taking in 1983 reached 1.55 $10^{38}\text{cm}^{-2}$ and 4,070 hours respectively (adjustments not included).

Tables 3 and 4 summarise the essential information on ISR statistics kept since 1971 when the first colliding beam events were detected (27th January, 1971).

**Acknowledgements**

Started in 1972 thanks to the initiative of D. Neet, F. Lemeilleur and G. Guignard, the Physics Run Analysis published on a 3 or 4 monthly basis has, with this last report, come to an end.

I would like to thank all the members of the Operations Group for their helpful comments and J-M. Geroudet for his valuable help in the upkeep of the run statistics. The continuing encouragement and interest of D. Neet is also gratefully acknowledged.

T. Verbeeck
Period 1

- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- GOOD CONDITIONS FOR R704 EXPERIMENT WITH PROTONS.
- L. IN I8=13 10E31, GOOD IN I8, FAIR IN I1+I4, BG STRUCTURE IN R1.
- FIRST UN OF THE YEAR, BAD AT THE START, GOOD AFTER BEAM ADJUSTMENTS.
- GOOD CONDITIONS, SPIKES IN R1, R1+R2 LOST, TEMPERATURE RISE FOR SO SHUNT, NO REFILL.
- GOOD CONDITIONS, SMALL LOSSES IN R2.
- FAIR CONDITIONS, MANY SPIKES ON BG DUE TO 18KV FILTER FAULT, PS FLUCTUATIONS.
- PERIOD WITH LARGE BACKGROUND, SPIKES IN R1, CLEAN-UPS MAINLY FOR I4.
- QUIET BEAMS, SOME SPIKES AND CURRENT LOSSES IN R1, MADE BACKGROUND WORSE.
- GOOD WORKING CONDITIONS, R1+R2 LOST IF COOLING PUMP FAULTY, REFILL.
- GOOD CONDITIONS, LOW CURRENT IN R2 DUE TO STACKING PROBLEMS.
- GOOD CONDITIONS, FAST DETERIORATION IN R1 FOR I8.
- VERY GOOD CONDITIONS IN GENERAL, CLEAN-UPS ONLY FOR I8 IN R1.
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<td>29.05</td>
<td>30.82</td>
<td>18.8</td>
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</table>

**Notes:**
- RUN: Run number
- NO.: Number of outlets
- M.O.W.: M.O.W. (Material of Work)
- STACK POSITIONS: Stack positions
- DENSITY: Density (in g/cm³)
- HEFF: Heat efficiency (in %)
- L INT.: Length of interest (in mm)

Period 2 to 5

**TABLE 2**
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**Period 2 to 5**
SPECIAL COMMENTS

1343  15
VERY GOOD WORKING CONDITION. IN GENERAL, CLEAN-UPS ONLY FOR 1B IN R1.

1369  22
GOOD CONDITION. 5-4 AMPs LOST IN R2 AND R1, R2 LOST DUE TO BEAM DUMP R2 FAULTY. NO REFILL.

1370  22
SPECIAL RUN FOR R210 WITH LUMS CALIBRATION.

1371  31  31
VERY GOOD WORKING CONDITION. IN GENERAL, CLEAN-UPS ONLY FOR 1B IN R1.

1372  31  31
GOOD CONDITION. SOME SPIKES WITH CURRENT LOSSES IN RING 1 + RING 2.

1373  31  31
MANY COND IN 4 GENERAL BUT LARGE SPIKES DUE TO 18 KV.

1374  31  31
GOOD CONDITION. BOTH BEAMS LOST DUE TO MAIN MAGNET DROP.

1375  31  31
GOOD CONDITION. SMALL CURRENT LOSSES IN BOOTH BEAMS. SPIKY CONDITIONS AT THE END.

1376  31  31
GOOD CONDITION. SMALL CURRENT LOSSES IN R2. R2 LOST DUE TO 2H216A SPIKE. REFILL.

1377  31  31
GOOD CONDITION. FEW SMALL CURRENT LOSSES IN BOTH BEAMS. SPIKY CONDITIONS AT THE END.

1378  31  31
GOOD CONDITION. MANY SPIKES IN R1, LARGE SPIKES DETERIORATE COND. (150MA LOST IN R2)

1379  31  31
GOOD AND STABLE CONDITION. R2 LOST DUE TO 2H216A FAULTY. REFILL.

1380  31  31
GOOD CONDITION. MANY LARGE CURRENT LOSSES (24) IN RING 2.

1381  31  31
GOOD CONDITION. BS INCREASED FOR 14+18. R2 LOST: UNKNOWN REASON. NO REFILL.

1382  31  31
GOOD CONDITION. IN 14+18, COMPUTER PROBLEMS. R2 LOST: UNKNOWN REASON. NO REFILL.

1383  31  31
GOOD CONDITION. CLEAN-UPS FOR 14 SMALL CURRENT LOSSES IN R1-R2.

1384  31  31
SPECIAL RUN FOR R210 WITH TERRILLER MUSIC CALIBRATION.

1385  31  31
GOOD IN GENERAL. MORE BG IN R2. R2 FOR 14 + 18. 4 AMPs LOST IN R2.

1386  31  31
GOOD CONDITION. BOTH BEAMS LOST DUE TO DIP ON 18KV, NO REFILL.

1387  31  31
GOOD BEAMS CONDITIONS. SOME SPIKES IN 18KV (THUNDERSTORMS).

1388  31  31
GOOD CONDITION. CLEAN-UP FOR 1B IN R1, R2 LOST: UNKNOWN REASON. REFILL.

1389  31  31
REFILL GOOD CONDITIONS. SOME SPIKES WITH SMALL CURRENT LOSSES IN RING 2.

1390  31  31
GOOD CONDITION. LARGE BEAM LOSS IN R2 (1.6A). BOTH BEAMS LOST DUE TO SOL DROP OUT.

1391  31  31
COMPARISON RUN FOR NEXT P-PBAR RUN, BOTH BEAMS LOST DUE TO TEMPERATURE FAULT. REFILL.

1392  31  31
GOOD CONDITION. R1 LOST DUE TO 1PFF9 TRIPPED. REFILL.

1393  31  31
R2 LOST AFTER A Q-SHIFT, REFILL.

1394  31  31
GOOD CONDITIONS IN GENERAL WHEN THERE ARE NO SPIKES.

1395  31  31
GOOD CONDITION. SOME SPIKES IN R2 DUE TO TEMPERATURE (73). GOOD WHEN NO SPIKES.

1396  31  31
GOOD CONDITION. NO SPIKES.

1397  31  31
GOOD BACKGROUND.

1398  31  31
GOOD CONDITIONS IN GENERAL, SEVERAL SPIKES IN R1+R2. 1.44 AMPS LOSS FROM R2, R2 LOST, REFILL.

1399  31  31
GOOD CONDITION. SOME SPIKES IN R2. R1 BLOWN-UP, CLEAN-UPS FOR 14+18.

1400  31  31
GOOD CONDITION. CLEAN-UPS FOR 1B IN R1.

1401  31  31
GOOD CONDITION. CLEAN-UPS ONLY FOR 1B.

1402  31  31
GOOD CONDITION. LARGE CURRENT LOSS IN R2 (1.6A). 18KV SPIKES.

Period 2 to 6.
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<tr>
<td>PHYS.</td>
<td>816.8</td>
<td>4133.8</td>
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<tr>
<td>TIME LOST</td>
<td>18KV → 193H + MPS → 137H + ISR → 392.6H = 722.6 HOURS</td>
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STATISTICS ISR FOR 1983