Session X

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OPERATIONAL EXPERIENCE WITH THE CPS FAST EJECTION SYSTEM

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1. EPICS AND POSSIBILITIES

Since its installation in the CPS early in 1963 the fast ejection system has been in operation for more than two years and it is appropriate to review the experience gained in this period, particularly in view of sharing the beam between several experiments.

After its first functioning in May 1963 the system was almost continuously in operation during the months June through September in conjunction with the CERN enhanced neutrino beam (1).

The additional facility provided at the first installation, i.e. single bunch ejection proved extremely useful, since it provides clean, short proton bursts of accurately known intensity. This was put to use during the above mentioned period for emulsion studies of the neutrino parent spectrum behind the magnetic horn (2, 3).

An experiment on small angle p-p scattering (4) was performed in the same period, using the extracted beam near the horn.

Though it was initially intended to use the entire proton beam for the neutrino experiment, the possibility was soon realized of taking small percentages from the beam for slow or rapid target bursts during the acceleration cycle before ejection. It proved thus possible to perform one or two additional experiments, yet eject practically the full beam intensity.

A start was made late in 1963 with the study of a second mode of partial ejection, i.e. to leave one, two or three proton bunches in the machine for internal targetting. This entirely electro-magnetic scheme would yield a much cleaner way of sharing. It permits experiments necessitating small fractions of the CPS beam to run in parallel with greater consumers using the fast ejection, such as the neutrino experiment. Successful tests early in 1964 proved the principles of the scheme. The development was pursued for making the equipment fully operational.

Beam sharing during the neutrino runs in 1964 was done by targetting before ejection. These neutrino runs proved efficient as is illustrated by Table I, containing statistics of one of the last periods.

Valuable experience was gained in summer 1964 ejecting the proton beam at an energy of 12 GeV. This was subsequently used for the design of the fast extracted beam for the precision g-2 experiment (5) planned for 1965. Also for use in the same experiment a start was made with the design of a device permitting the extraction of one to five proton bunches, leaving the remainder undisturbed in the PS.

In the meantime development of the radio frequency separators was nearing its completion. These are modulated by 8 μ s pulses and need short particle bursts, preferably from an external target. The east site ejection being only scheduled for 1965, the first r.f. separated beam was set up with a short burst from an internal target. A sophisticated scheme (6) was developed in test sessions during autumn 1964, involving the fast ejection kicker magnet, the actual beam target and three dump targets for protection of the ejection equipment from secondary radiation. This scheme has successfully operated during January through April 1965, serving the r.f. separated K^- beam (7, 8) for the British national hydrogen bubble chamber. In tre course of that run two additional targets were operated, taking a rapid and a slow burst from the beam before

its fast deflection onto the beam target by the kicker magnet.

One single bunch was ejected into the neutrino channel during a short run in April 1965 for tests of the enlarged CERN heavy liquid bubble chamber. This scheme is economic in beam and clean and proved very convenient in the above application.

Developments on the fast ejection bending magnet during 1964 resulted in a new coil and septum construction. The latter is now 3 mm thick and highly radiation resistent. It was installed in April 1965 and successfully operated in the following anti-neutrino runs.



During the anti-neutrino experiment, running for the entire month of May 1965 only 17 bunches were ejected into the neutrino beam. The remaining three bunches were subsequently steered onto an internal target in the east site.

In the machine shutdown of June/July 1965 a septum magnet for fast and slow extraction was installed in straight section 58 near the east area (9). Using this septum magnet and the fast ejection kicker magnet in the south the beam was ejected at first trial into the east experimental area during a recent test session.

The 1 to 5 bunch facility was installed at the end August of 1965 and successfully tested with the CPS proton beam at 11 GeV/c.

2. OUTLINE OF THE SYSTEM

As a complete description of the fast ejection system has been published elsewhere (10), only a short outline will be given here. A discussion of new installed equipment is given in section 3.

The fast ejection system extracts the beam in 2 stages (cp. Fig. 1). The 1st stage is formed by the so-called kicker magnet, excited with a rectangular current pulse. Its magnetic field rises in 0.1 µs, i.e. between the passage of 2 proton bunches. An angular deflection of 1 mrad given to the beam by the kicker magnet will, with the focusing forces acting in the synchrotron, result in a betatron oscillation of 15 to 25 mm amplitude in a D and F sector respectively. A septum magnet is placed with its septum a few mm from the unperturbed beam, 1/4 of a betatron wavelength downstream. The proton bunches deflected by the kicker magnet are thus placed into the aperture of the septum magnet which bends them out of the machine.

Both magnets small apertures, i.e. enough to contain the normal beam diameter with operating clearances of a few millimetres. They are for that purpose located in the CPS vacuum system and are brought into their working position in the second half of the acceleration cycle when the beam has sufficiently contracted. This is done by hydraulic servoactuators following electrical programmes. The actuators are outside the vacuum and transmit the movement to the ma gnets by a shalt through a sliding seal. A sectional view of the 2 magnets with their moving mechanism and vacuum tanks is given in Fig. 2.

TABLE I

The last neutrino run in 1964

						May				June						Total
						28	29	30	31	1	2	3	4	5	6	}
Extr. protons $(\times 10^{14})$						45	164	168	168	179	29	170	167	177	65	1332
Extr. efficiency %/0 .		•	•	•		86	90	92	94	95	86	89	89	95	96	91
Time loss due to:							:									
Ejection system %					•	1	5.3	0	0	0.1	0	0.	4.5	0	0	1.3
Beam transport %						0	0	0	0	0	0	0	0	0	0	0
Magnetic horn %						16	3	0.9	4.2	0	0	2.2	0.7	0	2.4	1.3
External causes 0/0						4	4.5	2.3	6.4	1	8.3	6.4	5.5	2.8	23	5

580









BENDING MAGNET

Fig. 2 - Sectional view of the fast ejection magnets in their vacuum tanks.



b) Modification for 17, 18 and 19 bunch extraction.



c) Modification for 1 to 5 bunch extraction.

Fig. 3 - Diagrams of some kicker magnet pulse circuits HV: Charging line from high voltage supply; LSL: Long storage line; S: Switch; SSL: Short storage line; A: Adaptor; G: Main spark gap; SCG: Short circuit spark gap; T1: 1st trigger generator; T2: 2nd trigger generator; D: Delay; pc: Pulse cables; KM: Kicker magnet; R: Matched terminating resistors.

The kicker magnet (11) is of the delay line type and the current pulse for it is generated by a line type pulser with adjustable pulse length, initially either 2.1 us or 0.1 us, corresponding respectively to total beam and single bunch ejection. The bending magnet (12) is excited with a half sine wave of around 150 µs base, derived from a conventional discharge of a capacitor, a crow-bar switch suppressing the current reversals. The pulse of the kicker magnet is synchronised on the crest of the bending magnet pulse. The main parameters of the system are collected in Table II.

3. ADDITIONAL FACILITIES AND IMPROVE-MENTS

The single bunch and total beam extraction initially installed in the CPS made use of a short and a long pulse forming network. The first had by its nature a short fall time and for the second the fall time is irrelevant.

For extraction of almost the entire beam, say, 17, 18 or 19 bunches out of the 20, the long magnetic pulse must be terminated with an adequately short fall time to leave the proton bunches remaining in the machine unaffected. The fall time of the magnetic field in a delay line magnet is roughly the sum of its delay time between passage of two adjoining bunches, and as for reasons elaborated in ref. 10 the delay time of the magnet is chosen 0.07 μ s, the fall time of the current should be, say, 0.03 μ s or less.

There are fundamental difficulties in realising a long rectangular current pulse with a steep descent with a lumped element passive line simulating network. The losses in a homogeneous line or cable produce a similar but weaker effect.

For this and other reasons (13) a different solution was adopted, i.e. short-circuiting the line at the required moment, thus cutting off the tail of the pulse. A spark-gap is incorporated for that purpose between the conductors after the main

TABLE II

Main parameters of the CPS fast ejection system

Kicker Magnet						
Number of units	2					
Useful beam aperture (heigth \times width)	$15 imes25~\mathrm{mm^2}$					
Length per unit	450 mm					
Pulse duration	2.1 μs 0.10 μs*					
Delay time	0.07 µs					
Characteristic impedance	$10.4 \ \Omega$					
Maximum kicker magnet voltage » line voltage	35 kV 70 kV					
Energy stored in line	260 J 13 J*					
Kick at 70 kV on the line	0.15 Wb/m					
Bending Magnet						
Useful beam aperture (height \times width)	$19 \times 40 \text{ mm}^2$					
Magnetic length	1.96 m					
Inductance	4.2 μΗ					
Onset of saturation effects at	1.5 Wb/m ²					
Current at 1.5 Wb/m² field	30 kA					
Charging voltage of capacitor at 1.5 Wb/m²	3.5 kV					
Movement						
Moving mass of kicker magnet	200 kg					
Stroke	250 mm					
Moving mass of bending magnet	450 kg					
Stroke	250 mm					
Plunging time (start to stop)	100 ms					
Withdrawal time (start to stop)	100 ms					

* Refers to single bunch ejection

gap and is triggered over an adjustable delay by a second trigger circuit. The principle was first proved with a trigatron-type gap, showing the possibility to terminate the current pulse in 0.02 μ s (cp. Fig. 4 c). The trigatron type of gap has not the required long term performance due to erosion of the trigger pin by the main discharge. A spark gap has therefore been developed to meet the specifications for this particular application: A wide voltage range and a high charge switching capacity, combined to low erosion.

The cut-off tai! of the current pulse will be repeatedly reflected between short-circuit gap and the other end of the line. For its damping a dissipative element must be present. It is formed by RC combination between long and short storage lines, whose other function is adaption between these two lines with sections of unequal time constants. The energy contained in the tail will mainly be dissipated in this resistor that must therefore have the adequate pulse rating. Absence of such dissipative element obviously results in a greater number of reflections, hence stronger erosion of the two spark-gaps and more severe duty of all insulating materials and surfaces. This limits the fraction of the pulse that can be cut off in continuous operation. Fig. 3 b gives a diagram of the thus modified pulse generator and Fig. 5 a shows a photograph of the assembled equipment.

The same principle is followed for the facility for 1 to 5 bunch ejection. The long storage line is replaced by one producing an 0.4 µs pulse. The pulse from both lines in series extracts 5 bunches, if the tail is cut off. Cutting off more gives pulses for 4, 3, or 2 bunch ejection. Opening the switch gives the pulse for single bunch ejection. In this application the adaptor and short storage line have changed places (cp. Fig. 3 c) and the short circuit gap is also operated during single bunch extraction. This results in current

pulses with a rise and fall time of $0.03 \ \mu s$. The 0.4 µs storage line has 4 lumped element sections. It is made of ceramic capacitors in a compressed air container as shown in Fig. 5 b.

A new coil and septum was developed for the bending magnet. Despite the high pulse voltage used it was possible to adopt a bare construction, the absence of insulation making the septum highly radiation resistant. It is composed of 14 water cooled tubes of 2 millimetres diameter, brazed together into a strip. With the 1 mm mumetal screen the septum has a total thickness of 3 mm. The leakage field integrated along the magnet could be held down to two per thousand of the equivalent integral inside the aperture, at a field level of 1.2 Wb/m². Fig. 6 gives a section of the septum magnet and a view on its extremity, revealing the new septum and its fixation.

4. GENERAL OPERATIONAL CONSIDERATIONS

Some operations, governing the relative position of beam and magnets, is common to the ejection schemes.

At the moment of ejection the beam has to be close enough to the septum, so that the kicker magnet can place the beam into its aperture. The kicker magnet must then also have engaged the beam in the homogeneous part of its field. Changing the relative position between beam and magnet can be done by a steering perturbation on the beam control, by a local closed orbit deformation or by radially moving the magnet. The south area septum magnet has a fixed radial position and steering has been used in the form of a "placing perturbation" that brings the beam in front of the septum shortly before ejection. It is long enough to make a beam position reading, which is conveniente for monitoring the constancy of the radial position at ejection. The amplitude of the kicker magnet mo-

a) Initial current pulse of long and short storage line in series. Time scale rimposed three current pulses with 0.4 µs/division.

b) Initial current pulse and supecut off tails, respectively for 17, 18 and 19 bunch ejection. Time scale and 19 bunch ejection. 0.4 μ s/division.

c) Current pulse for 17 bunch ejection. Time scale 0.2 $\mu s/division.$



Fig. 4 - Some current pulse shapes from the kicker magnet pulse generators.

vement is adjusted to engage the beam in that position. A closed orbit deformation is used for the stationary septum magnet in straight section 58, with a superimposed placing perturbation for fine adjustment.

The display of the beam position in the CPS is not accurate to within a few millimetres. More direct information on their relative position is obtained by intentionally intercepting the beam with the magnets. For the bending magnet this happens on the septum in the kicker magnet on its yoke. In both cases the interception is clear and sharp and can be suppressed by a 1 mm withdrawal of the beam.

No unwanted interception is encountered with the undisturbed beam when engaging it with a kicker magnet with an 11 mm shaving fork (10). The latter advances before the magnet and trims the beam in case it is too thick or vertically misaligned. Vertical clearance between beam and pole pieces is a few millimetres as can be proved by making interception using vertical bump coils. Deviation of this behaviour can be traced to targetting before ejection or to incorrect functioning of the CPS. To improve the beam geometry in the first case, a perturbation before ejection makes the beam scrape against a target placed radially 30 mm inward in straight section 15. This operation, called "shaving" has been proved useful and is hardly appreciable as loss of beam current.

In the case of total beam ejection up to 24 GeV the working margins are ample and with 50 kV line voltage of the kicker magnet the distance between beam and septum can be chosen from 0 to 5 mm. The omvement of the kicker magnet can be varied within \pm 5 mm, confirming the homogeneity of its field over 20 mm radial distance.

To allow adequate space for the temporary beam blowup during targetting operations after partial ejection, the beam must be well clear of the kicker magnet aperture and of the septum. Depending on the fraction ejected, separation of beam and magnets can be done in different ways: If beam control is maintained, by steering. If beam control is lost due to the fall in beam intensity either of the following three ways: 1) Ejecting before the flat top. The rising field then causes the remaining bunches to spiral inward. 2) Creating a local inward closed orbit distortion using bump coils. 3) Withdrawing the magnets. All these operations imply a certain dead time before and after ejection which can be around 10 ms for case 1), 30 ms for 2) and 30-100 ms for case 3), depending on the particular scheme.

5. SOME OPERATIONAL SCHEMES

a) Total ejection

Setting up this scheme consists only of correct positioning, as explained in section 4, and timing. This is simple and not critical and can be done in approximately 15 minutes. Operation consists essentially in an occasional correction of the drifting radial position of the beam in the CPS and in switching off the movement in case the CPS goes entirely out of control.

If part of the beam is used on internal targets before ejection the latter operation needs some more attention. Vertical and horizontal beam instabilities may be excited and the effective beam diameter can be increased. Greater fractions of the beam and faster targetting bursts lead to a stronger blow-up. A slow servo-target burst gives the least disturbance. The shaving operation has been shown to improve the beam geometry, hence reduce the interception on the magnet.

b) Single bunch ejection

The short magnetic pulse has some residual ripple left after its termination, and this can excite betatron oscillations of the order of 2 mm amplitude in a few bunches following the ejected one. The clearence between beam and septum must then at least be 2 mm in order not to loose these by interception. Synchronisation with the bunches must be well adjusted as the magnetic kick is essentially triangular and desynchronisation rapidly leads to a smaller deflection, hence kicking the beam onto the septum. Ejecting a single bunch has no observed influence on the beam position or stability thereafter. Subsequent targeting schemes are thus unaffected except for the time necessary before and after ejection for separation of beam and magnet Operation of single bunch ejection is almost as simple as total beam ejection, some precauctions being necessary in case of targetting beforehand.

c) Ejection of 17, 18 or 19 bunches

Beam control is lost shortly after ejection due to the sudden drop in beam intensity, and it is therefore not possible to separate beam and magnets by steering perturbations. If in this application 17 bunches are ejected around 20 ms be fore the flat top the rising field moves the beam approximately 30 mm inward and permits to bring the target into position in unit 60, near the east experimetal area. In the following 100 ms flat top the magnets are withdrawn. On the falling field after the flat top, the beam moves outward toward the target. Te beam can then be targetted in any of the conventional ways





Fig. 5 - Newly installed equipment.

b

a) One of the two pulse generators for excitation of the kicker magnet. 1) Long storage line; 2) Short storage line; 3) Adaptor; 4) Main spark gap; 5) Short circuit spark gap.

b) 5-bunch storage line. 1. Ceramic capacitor sections; 2. 10 Ohm pulse output connector; 3. Charging cable; 4. Charging inductor; 5. Pressure container.





Fig. 6 - Improved septum magnet in straight section 1. 1. Septum of copper tubes soldered together to a strip; 2. Return winding of same construction; 3. Mu-metal shield composed of 10 strips, 0.1 mm thick; 4. Insulation piece between septum and iron core; 5. Mylar sheet envelope on return winding; 6. Fixation strip for the latter; 7. Fixation plates for septum. Material for 4), 6) and 7) is fibre glass reinforced epoxy resin.

not involving beam control. In Fig. 7 oscillograms are collected of internal and ejected beam structure, around the moment of ejection, together with some CPS monitoring signals such as the magnetic field, the internal beam current, and the steering perturbation. The latter is a measure of the radial position and clearly shows the beam « gymnastics » involved.

Some subtleties were encountered in trying to keep the bunches undisturbed long enough for utilisation in the machine. Ejecting too early before the flat top obviously results in loss of the bunches on the inner wall of the chamber. Ejecting too close to the beginning of the flat top does not permit the beam to move away far enough from the septum. Beam control appears not to be lost instantaneously, but rather in a few milliseconds, as can be inferred from the rate of debunching. The voltage transient occurring in the beam control at the end of the rising field, may therefore still affect the position of the remaining bunches and deflect them onto the septum.

d) A 2 µs internal target burst

In this application the kicker magnet alone is used to deflect the beam onto a target in unit 60. The scheme is represented in Fig. 8. After the kick the deflected beam has a zero radial displacement in unit 60 and must therefore make another revolution to hit the target placed to the inside of the central orbit. The kicker magnet must kick inward so the beam passes in front of its aperture after the 1st revolution. In the single traversal of target 60 only a fraction of about 20% of the beam interacts and the remainder would hit on the yoke of the kicker magnet after the third revolution. Three heavy dump targets are therefore placed in such positions that by their combined effects of interaction and energy loss the radiation near the ejection equipment is kept to a low level. In order to obtain the correct radial displacement in target 60 during the second revolution the Q-value of the machine must be accurately adjusted. This is done by a quadrupole lens in S.S. 58 which distorts the closed orbit so as to produce the desired effect. Figs 8 a, b, c show the time structure of the internal beam as observed at relevant points of the CPS circumference and Fig. 8 d is a signal from a fast directive Cerenkov counter looking at the target.

A long servo-target burst and a rapid target burst, either by a rapid adiabatic deflector or by a fast perturbation, were taken from the beam before deflecting it by the kicker magnet. The operation of this beam sharing scheme requires

Session X





Lefthand column: Time structure of internal (upper) and ejected (lower) beam; time scale 1 μ s/division. Righthand column: CPS monitoring signals. 1. CPS magnetic field, biased so that only the field around the top is displayed; 2. Internal beam current intensity; 3. Steering perturbation on beam control (up is inwards); 4. Signal from radiation monitor near kicker magnet; time scale 100 ms/division.



Fig. 8 - 2 μs secondary particle burst from an internal target in unit 60.

Oscillograms: a) time structure of internal beam in straight section 58; b) idem in 67, showing interaction loss due to traversal of target 60; c) idem in 93, showing effectivity of the beam dumping operation in the second revolution after the kick; d) secondary particle burst, i.e. signal from a fast, directive Cerenkov counter looking at target 60; time scale 1 μ s/division. Central oscillogram: e) CPS monitorng signals: 1) internal beam current intensity; 2) zero level of the same; 3) CPS magnetic field, biased so that only the field around the flat top is displayed; 4) signal from radiation monitor in straight section 10; 5) signal from radiation monitor near straight section 97.

understanding and a good radial stability of the beam.

e) Ejection in the east experimental area

The ejection magnet in S.S. 58 is stationary and radially located outside the normal CPS aperture as shown in Fig. 9. The undisturbed beam is brought close to the septum by locally distorting the closed orbit with two pairs of bump coils as depicted in the same figure. This distortion is programmed to start shortly before ejection and is suppressed thereafter for utilisation of the remaining beam in case of partial ejection. The betatron oscillation induced by the kicker magnet is superimposed on this distortion. The radial orbit position on which the distortion is programmed must be between 10 and 20 mm outward from the central line so as to avoid hitting the inner wall of the vacuum chamber around S.S. 50 when applying the kick. This is done by a placing perturbation, which also gives a convenient fine adjustment of the clearance between beam and septum.

S.S. 58 is radially defocusing and the betatron oscillation has its maximum not in S.S. 58 but in S.S. 57. The radial displacement in S.S. 58 is therefore only about 60% of that obtainable at the fast ejection septum magnet in the south area. From this point of view operation in the east is more critical.

f) Ejection of 1 to 5 bunches

This scheme has been successfully tested at 12 GeV machine energy. The remainder of the beam has been shared between 2 long and 2 short target bursts starting from 17 GeV. Operation is similar to single bunch ejection, i.e. a greater clearance must be allowed between beam and magnet, rise and fall of the magnetic pulse must be correctly phased with the bunches and the magnets are withdrawn before further utilisation of the beam. Beam control remains effective but there is a small jump in the radial position of the beam due to the loss in intensity or to the introduction into the beam control of a greater percentage of the revolution frequency. This may influence the subsequent targetting in schemes that require switching on and off of the ejection. The position may be corrected by a perturbation starting right after ejection and this could be switched on and off with the latter, thus suppressing the effect.

6. CONCLUSIONS

After 2 years of operation a realistic assessment can be made of several aspect of the present design. Some doubts and fears have vanished in the course of time but some unpredicted aspects have arisen in return.

The performance of the equipment has been as designed for and in general is very satisfactory. Layout of the magnets, though originally planned for the south experimental area only, proved useful in other applications and will remain doing so for some time to come. The location of the kicker magnet and the bending magnet pulse generators in regions not accessible during CPS operation is an occasional handicap for maintenance.

The canned construction of the kicker magnet has performed electrically as predicted. Radiation damage to the polyethylene insulation and the epoxy resin screen in the gap has not been observed. However, under combined influence of radiation and electric field, gas is produced in the magnet slowly increasing its internal pressure. Releasing in involves opening the vacuum tank and this is undesirable. Though in careful operation time loss due to degasing can be kept low (cp. Table I) work is in progress to deal with this problem.

Though in total ejection the aperture leaves ample clearance for the beam, operation of targets before ejection can deteriorate the beam geometry such that interception can be observed, increasing the above mentioned gas production. Interception tests using vertical bump coils show that increasing the gap height by a few mm would completely solve this problem. The pulse shape could still be improved by better matching of the high voltage feeds into the vacuum. This would render partial ejection less critical.

The line type pulsers have functioned satisfactorily, and time loss due to these was negligible. No influence of spark gap wear was observed on jitter nor delay. Maintenance was done preventively by demounting once or twice a year and cleaning insulators and polishing spark gap electrodes. Not one single terminal resistor has failed in two years.

The bending magnet has performed as intended. Already in its original execution the mylar insulated septum had a life of over 1 million operations. The new, bare septum, is virtually insensitive to radiation and should have a much longer life. Vacuum feeds and flexible leads have given no concern.

The pulsers for the bending magnet have worked without failure since installation, and are still equipped with the original ignitrons. No deterioration in ignition or hold off voltage can yet be observed, nor in any other aspect of their performance.

The concern for hydraulics in general has gradually disappeared as the present system per-



Fig. 9 - Fast ejection from straight section 58 into the east experimental area.

Average closed orbit position is displaced between 10 and 20 mm outward. A local closed orbit distortion, centered around straight section 59, is created by a double pair of bump coils B1B2B3B4. This places the beam in front of the septum of the ejection magnet. The kicker magnet deflects the beam inwards, creating a betatron oscillation of enough amplitude to jump the septum. The oscillogram shows the signal from a fast directive Cerenkov counter looking at a target in the extracted beam. Insert shows a section through the ejection magnet and vacuum chamber in straight section 58.

formed run after run without interruption. Maintenance could be kept to preventive change of oil seals once a year for the bending magnet actuator and twice a year for the kicker magnet.

With the locally installed vacuum pump capacity the pump down time is less than 1 hour and the vacuum can be maintained around 4 to 6×10^{-6} mm Hg in operation, despite the less favourable materials that had to be used in the ejection equipment and the presence of the large sliding seals. The latter have given no trouble and inspection once a year has revealed neither wear nor radiation damage.

The controls proved functional and reliable. Programming of the hydraulic movement on the IBM patch panel is still too tedious. For this reason the hydraulic controls and programming are being simplified. This has already been done for other parts of the controls, in particular for the bending magnet.

Summing, up, the use and practicability of the system is proved by the physics (1-8) to which it contributed and its scheduled continuous operation in the year to come. Some imperfections, such as the radiation sensitivity of the septum, have been removed. Elimination of some others, like the gas production in the kicker magnet is in progress. At the same time its aperture will be slightly increased, such that beam interception after previous targetting will be suppressed. With these improvements and some simplifications under progress on the controls, the present design remains essentially free of inadequacies and good for another few years of operation.

Though total ejection for the neutrino experiments has up to now been a major application the present tendency for beam sharing is shifting the main interest to partial ejection. Calculations show that one single bunch on an external target is in many cases enough to serve a bubble chamber beam. A fraction of the CPS beam could therefore serve several bubble chamber experiments in parallel given enough ejection channels and kicker magnets. Multiple shot systems (14) are feasible, ejecting bunches of one and the same acceleration cycle into different channels with intervals of 20-50 ms. One single channel and single shot partial ejection can also serve several experiments simultaneously by splitting the ejected beam after ejection into different directions using fast switching magnets.

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Session X

- (10) R. Bertolotto, H. van Breugel, L. Caris, E. Consigny, H. Dijkhuizen, J. Goni, J. J. Hirsbrunner, B. Kuiper, S. Milner, S. Pichler and G. Plass: The fast ejection system of the CERN 25 GeV proton synchrotron, Int. Conf. on High Energy Accelerators, Dubna, 1963 (Atomizdat, Moscow, 1964) p. 669.
- (11) S. Pichler: The kicker magnet of the CPS fast ejection system, CERN Report NPA/Int. 64-27 (1964).
- (12) R. Bertolotto and G. Plass: L'Aimant à septum de l'éjection rapide du CPS, et son alimentation, in preparation.
- (13) H. van Breugel, J. Goni and B. Kuiper: Pulse generators for delay line magnets, paper presented to this conference, see Appendix.
- (14) D. A. G. Neet: Proposed electronic controls for the south hall fast ejection system of the proton synchrotron; CERN report, NPA/Int. 61-19 (1961).