

U.K. ACCELERATOR WORKING PARTYNotes on A.G. Proton Synchrotrons

These notes have been written, at the request of Dr. Stafford, on the present and hoped for future performance of the CERN PS, and to give some indications as to how a smaller machine for the U.K. might perform. They must be taken as only unofficial, personal estimates of performance and in no way as official CERN data.

I. Present status of CPS (March 14, 1960)

- a) Beam: normally $5 \cdot 10^{10}$ protons/pulse max.
best so far 10^{11} p/p (Linac buncher operating)
- b) Duty cycles:
- | | | |
|--------|--------------|---------------------------|
| 10 GeV | 60 pulse/min | (all with 40 ms flat top |
| 18 GeV | 40 p/min | |
| 25 GeV | 20 p/min | |
| 28 GeV | 12 p/min | |
- c) Targets:
- | | |
|-------------------------------|--|
| for counters | 30 ms with no fine structure |
| for chambers | 200 μ s with similar jitter |
| efficiency | probably > 50 o/o of protons die in target |
| two targets can run together. | |
- d) Operation: three days/week 8.30 - 22.00, with acceleration from 13.00.
About 10 hr/wk for nuclear physics.

IIa. Probable future development of CPS in next year or so.

- a) Beam: reasonable hope of going to $2-4 \cdot 10^{11}$ p/p by pushing present Linac and improving trapping in the synchrotron. Space charge effects may start to appear under these conditions.

b) Duty cycle: reasonable hope of being able to go to ~ 1 sec flat top at 25 GeV or below, with some reductions in repetition rate. With $3 \cdot 10^{11}$ p/p accelerated beam this gives:

<u>Energy</u>	<u>Pulses/min</u>	<u>Mean current</u>	<u>Target duty ratio</u>
10 GeV	30	$1.5 \cdot 10^{11}$ p/sec	50 o/o
18 GeV	15	$0.8 \cdot 10^{11}$ p/sec	25 o/o
25 GeV	8	$0.4 \cdot 10^{11}$ p/sec	13 o/o

For short target bursts, the mean currents will be higher:

<u>Energy</u>	<u>Pulses/min</u>	<u>Mean current</u>
10 GeV	60	$3 \cdot 10^{11}$ p/sec
18 GeV	40	$2 \cdot 10^{11}$ p/sec
25 GeV	20	10^{11} p/sec

c) Targets and ejection:

For counters up to 1 sec with no fine structure on internal targets,
up to 100 ms ejected proton beam, efficiency 10-20 o/o.

For chambers $< 50 \mu\text{s}$ on internal targets,
 $2 \mu\text{s}$ ejected proton beam, efficiency > 80 o/o

Target geometries such as to give very small spot sizes (e.g. 1 mm^2) in some cases.

Operation with several beams and/or targets together.

d) Operation: by the end of 1960, 112 hr/week, of which ~ 80 hr/wk should be available for nuclear physics.

IIb. Longer term developments

a) Increasing current up to the space charge limit in the synchrotron, if necessary rebuilding parts of the Linac. Present very tentative estimates are $\sim 10^{12}$ p/pulse.

- b) Efficient proton ejector for long flat top operation.
- c) Rebunching high energy beam to very narrow bunches for time of flight separation.
- d) Internal liquid H_2 targets.
- e) Storage rings.

III. Specific advantages of the A.G. proton synchrotron

- a) Simplicity, both of design and operation. The theory is simple and obeyed in practice; this comes partly because each stage of the whole acceleration process is independent of the previous one, and the machine can be adjusted for optimum performance step by step.
- b) Flexibility. The range of operation conditions, in energy, current, beam pulse length, is very wide. Targets and ejection devices are rather easily fitted in to the machine, and beams emerge with minimum of interference.
- c) Certainty. With good detail design and adequate execution it can hardly fail to work quickly and well, up to the space charge limit in current.

IV. Rough parameters for a 12-15 GeV machine, aimed at high intensity

A machine made from very similar components to the CPS, but with half the radius, would probably accelerate about the same amount of charge per pulse at the space charge limit; it would have convenient sized straight sectors, and a vacuum chamber only a little on the small side for efficient target operation. Increases in pulse current could only come from:

- a) Higher injection energy, but going to 100 MeV would only double the maximum current.
- b) Stronger focusing: not much increase is possible here without reducing magnet aperture, which will cause more loss of current than the potential gain.
- c) Increase of aperture: with an appropriate high emittance injector this would increase current, but will be limited by cost and need to maintain the field gradient.

I guess a factor of five gain in maximum charge per pulse over the CPS might be achieved by increasing the aperture and designing with high current as the principal aim.

Increase in repetition rate will be costly: with the increase in aperture, the power supply will be at least as large as that of the CPS, and a further factor 2 in $\dot{B}$ looks about a reasonable limit. This agrees with the radio frequency problem, where doubling the volts per cavity would again mean a large increase in the equipment.

The result is a 12 GeV machine with about ten times the potential mean current of the CPS, but costing, probably, more.

This section is necessarily rather speculative, and only a careful design study will be able to give reliable figures. The CPS general design took about two years, and looks rather well balanced for machines of this size: I doubt if more than the above factor of ten will be at all easy to obtain.

M.G.N. Hine

15.3.60

MGNH/gd

PS/1337

Please note that this paper is NOT an official C.E.R.N. document.

G. H. STAFFORD.
Sec. to the Working Party.