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MPS-SI/Note MAE/71-15
30.7.1971

PROPOSAL FOR A SIMPLIFIED AND CHEAPER FULL APERTURE KICKER SYSTEM FOR THE CPS

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1. SUMMARY

In this report we propose a simplified and thus cheaper FAK-system satisfying 28 GeV/c physics, ISR filling and 10 GeV bunch by bunch transfer to the 300 GeV-SPS requirements.

The proposed system consists of twelve 15 Ω magnet modules of the actual design located in one long and one short s.s. of the CPS. With a line voltage of 80 kV, a 28 GeV/c beam of $\varepsilon_H = 6\ \pi$ μmrad can be ejected. The system can eject up to 20 single bunches at different momenta within 50 μs intervals for most of 28 GeV/c physics applications. With the same spacing 20 bunches are sequentially transferred at 10 GeV to the 300 GeV-SPS.

For certain special requirements 4 bunches (or any firmly agreed number of bunches $1 < n < 4$) can be ejected at different energies within 100 ms intervals.

For the ISR filling and neutrino physics type experiments 20 bunches can be ejected every machine cycle.

Due to such a scheme and to several technical simplifications most of which have successfully been costed and applied to the 5 FAK systems of the Booster, the proposed system can be built for 2.4 Mfr.

2. USERS' ASPECTS

Since A. Brückner's scheme [1] for sequential transfer with 50 μs intervals between single bunches is considered as a serious possibility for ejection towards the SPS, we considered an extended application of this system also to 28 GeV/c physics, this with the aim of reducing the high costs of the presently proposed new FAK system for the CPS [2].

It was tempting to try to add a long 20 bunch line to the above scheme and to explore whether such a system satisfies all CPS fast ejection requirements. We have assumed that the CPS will first run (till 1975/1976) at an intensity of $\approx 4 \cdot 10^{12}$ p/pulse (s.c. intermediate exploitation of the Booster) and that the horizontal beam emittance will be $\varepsilon_H < 6\ \pi$ μradm.

Under these assumptions the users' aspects are as follows :

i) Bubble chambers (ref. Lazeyras, Bernard, TC Division)

When ejecting more than one bunch every 50 μs the bubble growth has to be checked. It varies with $\sqrt{\frac{T}{T-t}}$, $T \approx 6$ ms so that even for 10 bunches ($t = 500\ \mu s$) the increase of identical traces between the 1st and 10th bunch would be negligible ($\approx 4\ ^o/o$).

There are no problems related to gated wire chambers associated to bubble chambers.

ii) RF separators and beams (ref. Lazeyras, Bernard, TC Division)

The present RF separator pulse duration is 8 μs. For a 50 μs interval scheme this means that only 1 bunch could be accepted.

With $4 \cdot 10^{12}$ p/pulse it is believed that over 80 $^o/o$ of all RF separated beam experiments could be performed with only 1 bunch.

There are, however, cases where more than 1 bunch may be required, notably for 16 GeV/c K^- beams and 12-13 GeV/c $\bar{p}$ beams at a primary beam energy of 26 GeV.

At present 2 - 3 bunches are used.

iii) Other beams requiring high intensity (ref. Lazeyras)

For "Gargamelle" a 500 MeV K^0 beam may require more than 1 bunch even at $4 \cdot 10^{12}$ p/pulse in the CPS. In that case 50 µs spaced bunches could not be handled by the pulsed beam transport elements of the ejection 74 (too short flat top of sine wave excitation !).

iv) G-2 experiment (ref. Picasso and Petrucci, NP Division)

The experiment has been designed for a PS intensity of $2 \cdot 10^{12}$ p/pulse and for single bunches of 20 - 24 GeV/c. More than 1 bunch would only be required at PS intensities lower than $2 \cdot 10^{12}$ p/pulse. With $4 \cdot 10^{12}$ p/pulse the requirements for this experiment are largely satisfied with 1 bunch ejection.

v) The ISR (ref. Hübner)

At present the ISR are using 4 bunches for setting up the machine and 20 bunches for stacking. The 4 bunches are required in order to obtain sufficient intensity for the current transformers.

Even at a CPS intensity of $4 \cdot 10^{12}$ p/pulse it will still be desirable to have this ISR setting up facility by ejecting, say, 4 bunches (or less) spaced 75 .. 100 ns. For normal ISR filling a 20 bunch line would be used.

vi) Neutrino physics (ref. Wachsmuth, TC Division)

The same long line would be used for ejecting all 20 PS bunches or any number of remaining bunches in the machine ($n \leqslant 20$).

From ii), iii) and v) it is evident that a FAK system consisting of the 50 µs interval, single bunch facility plus a long 20 bunch line does not satisfy all fast ejection requirements of the PS.

We thus propose a system which will in addition be capable of ejecting a firm number of bunches (between 2 - 4), spaced 75 - 100 ns, this every 100 ms.

3. THE PROPOSED FAK SYSTEM

Fig. 1 shows the diagramm of the proposed lay-out : The system assumes magnets as designed by D.C. Fiander and P. Faugeras [3] i.e. twelve 15 Ω modules located in one long and one short s.s. of the CPS. Each module is connected by two parallel 30 Ω cables, and 4 modules form one operational group connected to one series of power supplies. Each group has thus the same voltage and is triggered at the same time.

Three different power supplies and lines are connected to each group :

i) A fast cycling 80 kV resonant power supply blocked by diode D_1' from ii) having a ferrite transformer, charges within 5 µs via diode D_1 the single bunch cable line, made of 30 Ω-, 80 kV semi-conductor clad "Suhner YT" type cable. The modules, assumed 120 m away from the power supplies, are connected via 2 parallel 30 Ω-, > 80 kV cables filled with SF_6.

The CX1171 English Electric deuterium thyratrons can be switched within 50 μs intervals.

This part of the system provides 20 single bunches ejected at one or at 20 different energies.

ii) Blocked by diode D'_2 from iii), the 80 kV resonant power supply with an iron transformer charges via diodes D_2 and D'_1 a, say, 3 bunch line within 5 ms. The repetition rate is equal to 100 ms.

The PFN consists again of 80 kV, semi-conductor clad "Suhner YT" type cables with a 30 Ω impedance. This part of the system together with line i) provides the "high intensity" 4 bunch facility every 100 ms.

iii) A second 80 kV resonant power supply with iron transformer charges via diodes D'_2 and D'_1 the 16 + 3 + 1 bunch line; the 15 Ω-, 16 bunch PFN is made of lumped elements. This part of the system together with lines ii) and i) provides the 20 bunch ejection.

In our scheme we do not foresee any energy dumping and (or) tail clipping thyratrons. The number of CX1171 tubes and the maintenance costs are thus at least halved with respect to the actual design. For single bunches the fall time (or tail) obtained by the short 100 ns cable line is satisfactory. (Measurements performed on Booster kickers resulted in a 3-4 ns fall time increase).

When ejecting 4 bunches, one first ejects one single bunch and then the 4 bunches in such a way that the tail falls in the "hole" created by the single bunch. The 20 bunch line does not need a fast tail, since no particles are left in the PS after this ejection.

3.1 The diodes

The diodes D'_2 and D'_1 should carry 1350 A during 2 μs and block 80 kV. Diode D_1 should carry 20 times 700 A within 5 μs and again block 80 kV. Diode D_2 should carry 3-4 times 2400 A during ≈ 5 ms and again block 80 kV.

Using e.g. the "Siemens" type "SS1 B06-80" or the "10-D-10" diodes 5 times in parallel and 140 times in series with a low inductance "tower" mounting, backed by a resistor grading system, one meets the above requirements and obtains a maximum blocking voltage of 140 kV. (Cost of material for one "tower" ≈ 1'000 Fr.) The single tower inductance can be kept as low as 200 nH. The splitting notably of the 20 bunch PFN's in four parallel 15 Ω groups and the introduction of the decoupling resistors $R_1 \ldots R_3$ are necessary in case of an erratic firing of one tube only. The resistors then limit the peak currents in the diodes D'_1 and D'_2 and in the erratic tube to a safe value.

3.2 The fast cycling 5 μs charging resonant power supply

A system with primary capacitor banks (one per bunch) charged to 15 kV, 20 cheap primary tubes of type 5949 and a H.V. ferrite pulse transformer is envisaged.

4. SIMPLIFICATIONS WITH RESPECT TO THE ACTUAL DESIGN

Oil housings for H.V. thyratrons are useless and expensive complications. H.V. thyratrons of "English Electric" can produce a current rise of $\approx 100 \frac{A}{ns}$.

In the case of free (in air) mounting, the stray inductance is responsible for approximately 25 % of this rise. Using oil housings these 25 % can be reduced to 15 %. 75 % of the current rise is due to the gas discharge built up and cannot be influenced by closer housings. The 10 % gain in stray inductance does not compensate the costs and complexities of an extensive oil system.

Cable terminating plugs can be of commercial type (Cossonay) and cheaper than specially made H.V. plugs.

Terminating resistors can be made cheaply of constantan wire (s.c. Schniewind bands).

Although we have in our proposal assumed an ≈ 120 m distance between the FAK modules and the power supplies and thus provided for SF_6 filled transmission cables, one should seriously investigate the possibility of building a hut adjacent to the FAK in the ring which would permit to get rid of the SF_6 cables and to replace them by shorter and much cheaper semi-conductor clad ones.

5. BUDGET BREAKDOWN FOR THE PROPOSED SYSTEM

Table 1 gives a detailed cost breakdown for the proposed FAK system. The total price amounts to 2.434 kFr.

This figure has to be compared with the actual proposal [2].

	kFr	
Stage 1 (9 modules)	2.371	
Stage 2 (3 modules)	904	
Expenditure stage 1	128	
Up-rating for 6 shots	200	
Ejection towards SPS	1'000	(half figure of [4] taken !)
Total	4.603 kFr	(civil engineering again excluded)

TABLE 1

Elements	Unit price kFr.	Number per 1 m of s.s.	Total price per 1 m of s.s. kFr
80 kV power supply for 20 bunches	50	1	50
80 kV power supply for 3 + 1 bunch	30	1	30
80 kV fast cycling 20 x 1 bunch supply	130	1	130
Diode towers	1	18	18
Resistors $R_1 \ldots R_3$, mounting	1	16	16
Cathode plugs, heaters etc. (four times)	30	1	30
CX1171 thyratron	11	4	44
Trigger devices (four times)	10	1	10
15 Ω- 20 bunch PFN	20	4	80
1 bunch and 3 bunch semi-conductor cable line	0.5	32	16
SF_6 transmission cables	0.1/m	1 km	100
Kicker modules	25	4	100
Vacuum tanks	50/1 m s.s.	1	50
Matching constantan resistors	1.5	4	6
Vacuum feed-throughs for 50 kV pulses	0.4	16	6.4
Cable termination plugs	0.5	50	25
Controls, interlocks, low power electronics	50	1	50
Metallic mountings	50	1	50
Total for 1 m s.s. of PS			811.4
Total for 1 + 2 m s.s. of PS			2.434.2

[1] A. Brückner : A proposal for 20 x 1 bunch or 10 x 2 bunch ejection from the CPS to the 300 GeV machine, based on a new fast charging system.
MPS-SI/Note 300/INJ/2, 21.9.1970

[2] D.C. Fiander : A design proposal for a full aperture kicker system for the CPS.
MPS/SR/Note/71-3, 5.2.1971

[3] P.E. Faugeras : Preliminary calculations of a kicker magnet.
MPS/SR/Note/69-19, 14.11.1969

[4] ----- A design of the European 300 GeV facilities.
Chapter 2-16, MC/60, page 28, Table 3.8

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Fig 1. SCHEME OF FAK SYSTEM FOR 1m STRAIGHT SECTION OF PS.