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PROPOSAL FOR A NEW PS FAST EJECTION SYSTEM TOWARDS THE WEST HALL AND THE ISR

(Second draft as discussion basis)

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1. Comments to first proposal (MPS-SI Note MAE 68-4 from 12.8.68)

Comments have been received from DL (P. Standley) the SR (O. Bloess and G. Plass) and MU (G. Munday) groups. The first test runs of the FAK 66 with the PS-beam provided useful evidence for the design and testing of any future fast ejection system. Better estimates are available as to the longitudinal phase-space of a high intensity PS-beam after completion of the Booster.

The main objections to the first proposed new kicker system can be summarized as follows :

i) An oil insulated ceramic vacuum chamber kicker could not be accepted for safety reasons due to the danger of a chamber failure in the ring. The probability for such a fault occurring cannot be dismissed, even if relevant laboratory tests were successful.

Charge effects due to the high resistivity of a ceramic chamber may also have adverse effects on the PS-beam.

ii) In order to reduce the number of straight sections for the new kicker system, polarity changing facilities should be incorporated in order to be able to eject with the total number of kicker modules from either s.s. 16 or from s.s. 58 (74).

iii) With a high intensity PS and the Booster in operation, the bunch length will increase. It is estimated that a T = 75 ns kicker field rise-time will be required instead of the present 95 ns-figure.

iv) Three different intervals between pulses during one PS machine cycle have been forwarded : 100 ms for "normal" multipulsing at one or two machine flat tops, 40 ms or ejection at 2 $\frac{GeV}{c}$ - momentum intervals during acceleration in the PS and 3..5 ms for a special requirement, the multipulse ejection towards a future muon storage ring.

v) The compatibility of any new fast ejection system with PS operation should be demonstrated at an early stage of the kicker project.

2. Proposed modifications

In view of i) ...v) the following modifications to the initial project are suggested :

i) Magnet Design

We now propose a non degassing ferrite and metallic plate full aperture, vacuum insulated kicker module system with a PS F-section aperture of 52 x 146 mm^2.

We are also investigating the possibility of using a magnet with conductors which instead of being rectangular would have a quasi-elliptic shape embracing the PS vacuum chamber contour and with a uniform field in a 58 x 20 mm^2 ejected beam region. By doing so it is expected to reduce the effective magnet inductance and the rise-time T_r. We would, however, consider this saving as a reserve for compensating the various inevitable rise-time increases due to factors enumerated later on.

The main parameters of a single module are summarized in Table I :

Table I

Inductance	$L = 1.8\ \mu H$
Capacitance	$C = 2.7$ nF
Theoretical rise-time (3% ... 97%)	$T = 70$ ns
Expected rise-time (3% ... 97%)	$T_r = 75 \ldots 80$ ns
Impedance	$Z = 25\ \Omega$
Magnetic field	$B = 525$ G
Current	$I_{max} = 2.17$ kA
Module length	$\ell = 0.47$ m
Magnet voltage at 28 $\frac{GeV}{c}$	$U_{m_{28}} = 54$ kV
Magnet voltage at 26 $\frac{GeV}{c}$	$U_{m_{26}} \doteq 50$ kV
PFN-voltage	$U = 100$ kV

In view of the reserve due to the assumed large radial beam dimensions we propose to limit the maximum operating PNF-voltage to 100 kV. To obtain the required kick at 26 ... 28 $\frac{GeV}{c}$ momentum, eight modules or two short plus one long (or four short) PS F-straight sections would be necessary.

We propose to use as far as compatible and applicable the FES-group mechanical polarity switch to interchange input and termination of every module for polarity inversion. Polarity to be ultimately exchangeable between two machine cycles and in the middle of one machine cycle for ejections + |- + |- + |... and + |- + |+ - |.... . By connecting the terminating resistors to the magnet via matched cables, the switching operations could be performed in a central ejection building.

As to the dielectric strength of the proposed kicker magnets one can mention the first results obtained with a Booster kicker module of very similar full aperture design : The module with the same 10 mm distance between opposite polarity plates and the same 10 mm vacuum insulated distance between conductor and opposite polarity plates had been tested with pulses up to 55 kV of several ns-duration and at a rather modest vacuum of 10^{-3} Torr.

The forming process was rather fast. The dielectric strength of the proposed modular magnets remains, however, to be demonstrated.

Faced with the problem of a shorter field rise-time of 75 ... 80 ns in the magnet, we propose to follow two ways in order to find a satisfactory solution :

i) By experimenting with large arc diameter, 120 kV- and 80 kV nominal voltage "English Electric" deuterium thyratrons, the first to be used as the main switching element and the second as tail clipper.

Recent extensive low voltage full scale model measurements confirmed previous results that a still permissible incoming current (and voltage) pulse rise-time T_i equal to about half the computed and required field rise-time $T_i \doteq \frac{1}{2} T_r$ ($T_r \rightarrow 3\% \ldots 97\%$) will give a satisfactory T_r in the magnet and also result in a low magnetic field flat top ripple.

We are thus faced with the problem of achieving a 35 ... 40 ns rise-time in the thyratrons at 100 kV and 50 kV (clipper) this for 2 kA-and 4 kA-pulses. Taking Fig. 5 of MPS-SI Note MAE/68-4 a maximum deuterium pressure regulating voltage of ≈ 6 V would be required. A set of parameters will have to be adjusted notably for the clipping thyratron such that it does not switch under the influence of the main 35 ... 40 ns rise-time incoming pulse and, when triggered, still clip with the same rise (or fall) time.

If feasible, the thyratron solution would have a certain advantage due to its jitter free operation which is of importance with the now required reduced field rise-time of 75 ... 80 ns.

ii) A recent modification of the 110 kV FAK-spark gaps by introducing the FES-group type ring electrodes and pulsed corona system gave very good results. 95 ... 99% of pulses somewhat above 100 kV were found within a 10 ns range. Spark gaps of this type could thus be used as main switching and tail clipping elements as an alternative to i). There is, of course, no problem associated with the rise-time, which is of the order of 5 ... 15 ns in these gaps.

For the transmission of the 35 .. 40 ns rise-time voltage and current pulses, 50 kV, attenuation free cables without semiconducting layers will be required. It will have to be investigated if non pressurized polythene cables will safely withstand the required voltage. Such cables would result in a considerable simplification of the project.

The importance of the three forwarded multipulsing intervals of <u>100 ms</u> for normal flat top operation, of <u>≈ 40 ms</u> during the PS rise and of <u>3 .. 5 ms</u> for a new muon storage ring experiment can be summarized as follows :

i) Our first proposal was based on a resonant changing power supply for the pulse forming network (PFN) through a premagnetised HV-transformer at a 100 ms repetition rate. One of the limiting parameters for this supply is the time required for rebiasing the transformer. As to repetitive changing it is estimated that a 40 ... 50 ms-interval would still be possible to obtain, either with a biased transformer or with an unbiased one of adequately increased size and power, where only half of the total magnetic flux range would be used.

As to the switches, spark gaps have already worked at 100 ms interval multipulses. Further work would be required in order to improve the jitter under these conditions, but it is believed that satisfactory performance could be achieved with FAK-type gaps improved by the FES-group triggering arrangement.

Further extensive tests would be required to prove the feasibility of multipulsing at 40 .. 50 ms intervals.

Deuterium thyratrons, which are built for A.C. operation up to 2 kHz should allow double- or multipulsing at 100 ms and 40 ms intervals. However, here again extensive tests are required to check the thyratron performance at this repetition rates and the high current pulses.

ii) At 3 ... 5 ms intervals between consecutive pulses one can no more adopt the premagnetized transformer solution. Transformers with about 20 times higher apparent power would be required to be progressively saturated by the applied pulses.

Since any muon storage ring ejection could be preceded and (or) followed by normal ejection operations this at, say, 100 ms-intervals, one could not envisage any switching during that time to a second, more standard charging device. This means, that the entire charging system would have to be built for a 3 .. 5 ms repetitively charged 20 bunch PFN, as the ejection of any number of bunches is obtained by clipping an initially 20 bunch PFN-pulse. The main problems are, however, encountered with the switches. No experimental data are available about the behaviour of spark gaps at 3 .. 5 ms interval discharges and it is quite probable that no satisfactory operation can be obtained due to too short deionisation time or excessive jitter. Deuterium thyratrons may stand a better chance, but no promise or statement can be made at this stage, no experimental evidence being available.

We therefore propose to basically develop a 100 ms interval multi-pulse system comprising reliable operation of resonant charging supply, main switches and tail clippers. Successful operation achieved, 40 .. 50 ns ejection intervals can probably also be obtained at a later date. A 3 .. 5 ms repetition ejection should be considered as a separate development requiring 1 - 2 years after the complete kicker system is installed and in operation.

As to the preselection of kick strength and of the number of bunches to be sequentionally ejected from cycle to cycle, decisions could be taken at a later state of the project. We would consider to use and incorporate any FES-group "straight-flush" electronic development compatible with our project.

3. Proposed schedule

In view of the importance of the project, the limited available staff and in order to limit and control the expenditures we propose to develop the new PS fast ejection system in two stages :

Stage I

During this stage the main feasibility of the project and its compatibility with the operation of the PS shall be demonstrated. The activities are :

i) Construction of a low voltage full aperture magnet module with an effective 75 .. 80 ns (3% ... 97%) magnetic field rise-time, determination of magnet parameters and of longest permissible voltage and current rise in the switch.

ii) Construction in accordance with i) and testing of a H.V. vacuum insulated kicker magnet module with a 120 kV maximum voltage resonant power supply, to charge a 2 μs lumped element PFN to 100 kV, and main switch (large arc diameter 120 kV nominal voltage deuterium thyratron and/or spark gap).

Laboratory tests should prove the ability of the module to be continously operated at 50 kV (magnet) pulses, the 75 ns magnetic field rise-time and the stability (jitter) of the switching system.

(Preliminary work for this stage has already started: The low voltage magnet module with ferrite cores is actually being measured. The construction of a 120 kV resonant power supply is well advanced. The "English Electric Co." has manufactured one 120 kV- and one 80 kV- large arc diameter deuterium thyratron to be sent to CERN for trial with our project within the next days).

Towards the end of the long 1969/1970 PS shut down at earliest we propose to install the kicker module for a limited period in a short F straight section, preferably in one of the sections retained for the new fast ejection kicker system, with the aim

a) to demonstrate the kicker module compatibility with normal PS-operation (no influence on injection and acceleration).

b) To check the influence of the PS-beam on the kicker performance notably on his dielectric strength (charged particle effect in crossed electrical and magnetic fields).

c) To verify the kick strength of one module.

d) To definitely agree upon the final system parameters and performance. We would like to stress this point for the following reasons : In all parameter computations, idealized assumptions had to be made although it is known that due to the impossibility to correctly match elements like thyratrons or spark gaps, connections, polarity switches, and so on, the total circuit inductance and the field rise-time will increase and the kick strength at constant applied voltage decrease.

At this stage the relation between field rise-time and straight sections for a required kick strength and momentum can be given and agreement reached on the number of modules to be installed in the PS.

Stage II

During this stage the tail clipping technique shall be elaborated and tested, the multipulsing, polarity changeover and sequencing equipment developed and tested and an ejection setup consisting of two modules with the ejection parameters variation facilities life tested.

Only after successful tests shall the series production of the entire modular system be launched.

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Distribution :

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