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STATUS REPORT ON THE FAST EJECTION SYSTEM FOR CHANNEL A OF THE SERPUKHOV 70 GEV PROTON SYNCHROTRON

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1. General

The system described in the Design Study[1] of August 1967 and based on a layout proposed by IHEP[2] in June 1967 corresponded to the commitment of CERN to eject the protons into channel A of the Radio Frequency separated beam of the Mirabelle bubble chamber, as stipulated by the Convention (Annex 1, paragraph 1). The layout[3] proposed by IHEP in January 1968 and adopted by CERN in March 1968 is remarkable and above all much more ambitious. With this layout CERN has accepted to contribute to a polyvalent system permitting to eject the beam through septum magnets that could be placed at appropriate points anywhere around the azimuth[3], yet keeping the full commitments for the equipment of channel A. Since three fast ejection channels A,B, and C have been foreseen, the IHEP experts have asked[4] that the system of kicker magnet and intermediate septum magnet be able to eject twice in each acceleration cycle into each of these channels, that is that they be able to ensure the totality of ejection needs of the accelerator.

Since suppression of the closed orbit deformations necessitates acting upon a central orbit, it will be difficult to use the old proved CERN construction for the kicker magnet. It is now likely that either a small aperture variant with moving polepieces or a full aperture magnet will be used. The intermediate magnet and its moving mechanism constitute substantial additions to the obligations of CERN, the departure from the well proved techniques entails the necessity for additional prototype work before the final technical plan can be formulated. Finally the request for additional multishot facilities formulated by IHEP would, if they were agreed to, entail consequences in the entire project which are in no way trivial.
For these reasons it was decided in March of this year to spend the remainder of 1968 in a more detailed design study of the newly adopted variant, including some model and prototype work. This study is now under way.

2. Layout

The present plans follow closely the latest layout, proposed by the IHEP[3] early this year.

Since that date the trajectories, deflections and optics have been verified by computations at CERN and, in consultation with the external proton beam transport group of the NPA division, proposals have been made for a final trajectory and target position[5]. The proposal is made in form of a restricted target area within which the IHEP will be free to choose a final target position and therewith a trajectory at their convenience. This was considered logical in order to leave some flexibility for the layout of the target station and the surrounding shielding. This shielding system around the external target will probably influence the exact position of the latter, and the nature and dimensions of this shielding seemed not yet adequately cleared in connection with the philosophy of personnel access to this channel and neighbouring beams during accelerator operation. Pending further study on these points, no choice of a final target position and trajectory has been made at the joint meeting of experts in June 1968. At the request of the IHEP, CERN has produced a paper[6] with a number of considerations on shielding requirements at 70 GeV as can be extrapolated from experience at the CPS. The paper is written in the spirit of recommendations made by a consultant since, due to its possible interrelation with several adjacent secondary beam channels, the shielding around the external target station must remain the responsibility of the IHEP.

The influence of the tolerances of relevant parameters of the accelerator, the ejection and the proton beam transport in the performance of the extracted channel A, has been studied in both IHEP[7] and CERN[8]. The two studies come to similar conclusions. The quoted accelerator beam diameter of 10 mm in conjunction with typical tolerances for the accelerator, ejection and beam transport equipment leave only a small margin in the position of the maximum beam envelope (lens Q3 of the beam transport) and focusing spot on the target. Since the spot size and acceptable divergence at the target are approximately matched by the beam emittance, it would not help very much to increase the aperture of Q3. Further reducing the tolerances of the equipment would lead to rapidly increasing difficulties of manufacture and would gain but little on the working margins. Increasing the aperture of the beam transport or reducing the tolerances of the latter and of the ejection equipment would then be of limited use since the greater incertainty would be in the accelerator beam emittance anyway, which for higher intensities may increase by a substantial factor. A possible way of handling an increased emittance would therefore be to make the beam envelope fit the aperture and accept the ensuing defocusing effect at the target, which would only reduce the secondary particle production but not affect the separation. It was decided that the evolution of the accelerator beam emittance must closely be followed and that the equipment will be designed keeping in mind that the largest possible good field region is desirable.

During a number of discussions between ejection specialists from IHEP and CERN it was concluded that the location of the pulse generators and power supplies for the ejection equipment in the accelerator ring tunnel would be highly impractical and would lead to serious difficulties. This is due to inaccessibility during accelerator operation and due to the simple inadequacy of the available surface area. In view of the plans for a second fast ejection channel B, to be constructed by the Research Institute for Electrophysical Apparatus in Leningrad, furthermore a slow ejection channel, and considering the similar needs for the external proton beam transport and possible supporting equipment as closed orbit deformations, it was being judged good policy to concentrate all this apparatus in a building separate from the ring tunnel but close to the ejection area. This building would then specially be layed out to house all ejection material except the magnets proper. In particular a proposal[9] has been formulated by CERN for the disposition of the ejection equipment of channel A in one of the two equipment rooms, the other one being provided for the external beam transport system. A local control room is foreseen in which the controls of the ejection system will be concentrated. It is presently understood that the construction of such an "ejection building" has meanwhile been agreed to by the USSR State Committee for the use of atomic energy.

During years of operating and constructing such equipment at CERN it has proved overwhelmingly difficult to eliminate the interference between adjacent high level pulse equipment. Furthermore virtually every measurement is rendered impossible near this working pulse equipment. In view of this and in view of the great number of such equipment concentrated in this building, it is judged essential to group the high voltage pulse equipment on one hand and high current pulse equipment on the other hand in two separated shielded rooms.

In addition the local control room must be shielded. Failing to follow these recommendations will result in a loss of many months time in "debugging" the systems, with a remaining probability of inadequate results. Preliminary specifications(10) for the shielding, doors, windows, cable traverses and earthing of these rooms have been formulated by CERN.

During the Joint Meeting of Experts of March 1968, CERN accepted to supply all interconnection cables between ejection and beam transport equipment insofar as they are in the ejection building. All other cabling would be the responsibility of the IHEP, excepf for special cables not available in the USSR. To help the IHEP in planning this work CERN presented a preliminary calbe plan(11) to be used as a first orientation for the installation experts at the IHEP.

A first estimation(12) of the foreseen utility consumption by the fast ejection equipment has been made and presented to the IHEP. These estimations will be made more precise when the detailed design study of this new variant has been completed and a choice has been made of the mode of multishot operation, i.e. early in 1969.

A crucial decision to be taken by IHEP is concerned with the question from what place actually to operate the ejection systems. Obviously the ideal is concentration of all controls in the main control room. However, by adoption of the ejection building and hence of the local control room, a slightly biased situation is being created, which, together with the lack of space in the main control room, cannot be ignored. Another variant may then be considered. These and other considerations (the socalled control philosophy), partly based on observation of the evolution around the CPS, and taking into account the opinions of experts responsible for operation and maintenance of the CPS, have been collected in a paper(13), which is meant to stimulate and to give some background to the discussions. It is good for the IHEP to realize that this decision will influence the life around the accelerator in the coming 10 - 15 years. For CERN a decision on this point is necessary in the next few months in order to continue the detailed design of the electronics.

3. Kicker Magnet System

As stated above this magnet will either be of the small aperture type with moving polepieces, or of the full aperture type. A number of model experiments have been carried out, most of which are directly relevant for the two solutions, although they were made on a full aperture model.

Some resistive paper model work was persued, which aimed to study the possibilities of flux reduction in full aperture magnets by introducing a partial shielding on the polepieces. This study(14) yielded the result that the voltage could probably be reduced by 20 o/o - 30 o/o if a reduction of the good field region to widths of 30 - 20 mm and a further decrease in impedance level is accepted. Alternatively, the flux reduction can be used to reduce the number of kicker magnet sections, keeping the impedance, hence the voltage, constant.

The second model was aimed to investigate the possibilities of obtaining conveniently short rise times with a lumped inductance kicker magnet with voltages comparable to those of a delay line magnet. If this were so it may be possible to simplify the construction of the magnets, which would be particularly interesting for full aperture magnets. This study(15) was carried out theoretically and experimentally. The latter at low voltage but at the true impedance level and time scale. A full size low voltage model of a full aperture magnet unit has been constructed for and used in this study. The conclusion here is that, by accepting a few percent overshoot of the magnetic pulse and some reflections due to an unmatched network, it is possible to obtain field risetimes identical with those of magnets of delay line construction.

The reflections ensuing above could for the greatest part be rendered harmless by use of a saturable inductance in series with the short circuit sparkgap. Since such a scheme poses additional problems of triggering this sparkgap and since calculations become rather cumbersome, a reduced high voltage model, comprising delay line, three sparkgaps and triggers were constructed and the behaviour of these were studied in conjunction with the full size kicker magnet model. The results confirmed the predictions(16).

A full size full voltage prototype is now being designed to study the exact implications of the above findings in a complete engineering execution and to compare them with the classical solutions. This prototype is meant to be studied in parallel and to support the detailed design of the final magnet.

A study is presently being made about possible fast charging schemes in view of the multishot applications. An internal report[17] has been issued on the design of a resonant charging scheme.

4. Septum Manget System

A more detailed design study of the septum magnet system has begun. This study is at present mainly centered around fast capacitor bank charging, in view of the repeated shot requirements. It is aimed at comparing the scheme of fast charging between shots with an alternative scheme where the energy for several shots is stored in separate capacitor banks.

Another question presently under study is the pulse transmission from the ejection building to the septum magnets. The complexities of long, low inductance transmission lines are being compared to schemes using higher impedance and voltage levels and a step down pulse transformer near the magnets.

Like for the kicker magnet it is aimed to study a prototype magnet as support for the detailed design phase of this part of the project.

5. Vacuum system

On the basis of the design study of Aug. 1967 degasing flow rates have been estimated and required pumping rates have been calculated[18] for maintaining convenient average pressures in the accelerator vacuum system. These results have been discussed with the IHEP and preliminary agreement has been obtained. Following the above considerations a preliminary design[19] has been made, stressing the principles according to which one wishes to proceed for materials, seals, pumping, controls and interlocks.

It was agreed in March 1968 that CERN supply the tanks containing the ejection magnets and all their supporting equipment. The IHEP would manufacture all modified doughnut chambers and the bifurcation chamber ("pantalon").
For these CERN has provided the IHEP with preliminary specicifications[20] based on the trajectories chosen and providing some margin of operation.

6. Moving mechanisms

A detailed design study of the hydraulic servoactuator system for moving the intermediate septum magnet (and possibly the moving polepieces for the kicker magnet) is now well advanced. Similarly for the hydraulic pumping station for which preliminary contacts with the industry have been taken up. A prototype actuator is now being designed to study the details of the servoloop stability and the optimum distribution valve characteristics.

7. Electronics

The whole of the proposal for the electronics set forth in the design study[1] of August 1967 will essentially be followed. However, the adoption of the new variant in March 1968 will require additional facilities in the control and interlock system, the timing system, the monitoring system and the beam diagnostics. This is due to the introduction of the intermediate septum magnet and in order to allow for flexible multishot facilities and compatibility of the two fast ejection channels A and B. These problems are now studied as a whole. Since early 1968 and in parallel with the above activity a detailed study has been going on of the beam diagnostics and concomitant data reduction and display. This had now reached an advanced stage and an interim report has been issued[21].

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