

BEAM DUMPING AND SCRAPING IN THE CERN INTERSECTING STORAGE RINGS

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(presented in summary by M. J. de Jonge)

Abstract

The high intensity of the beams stacked in the CERN ISR called for the design and construction of a system capable of dumping the beams before they hit the vacuum chamber under fault conditions and of concentrating the induced radioactivity into a small region. The dumping system of each ring consists of four air-core full-aperture pulsed magnets which deflect the beam vertically onto an absorber block. The systems for the two storage rings have worked correctly from the first ISR runs with repetitive or manual triggering. The automatic triggering required for the sudden need to eliminate a stacked beam is being completed.

Scraping targets are required for protecting the injection kickers from the phase-displaced tail of the beam during stacking, and for removing low-density halos from the stack. The targets consist of scattering foils located in azimuth such that the scattered protons are mainly intercepted by the absorber block of the beam dumping system.

1. Introduction

The risk that the high intensity stacked beam hit the vacuum chamber on a particular point and transform there its 1.8 MJ kinetic energy into heat, called for the design of a system capable of disposing of the beam very quickly. It was therefore decided to build a system kicking the beam in a way similar to normal fast ejection, in order to dump the beam even in the occurrence of a very fast loss. The system should also be able to eliminate the beam after repetitive injection, during a long test period, and concentrate the induced radioactivity in only one region of the ISR. The dumping system of each ring consists of four full-aperture pulsed magnets which deflect vertically the beam onto an absorber block situated in the same straight section. In order to fit the requirements of induced radioactivity concentration, the systems for the two rings are placed in the same intersection region I_3 , Fig.1. The vertical β function being small in this region i.e. the beam being flat it was possible to consider pulsed magnets without ferrite yoke which allowed a cheap and quick construction of this important part of the project. The equipment needed to energize and control the magnets was installed in a nearby equipment building, permitting free access during a run.

2. Description

Each magnet is connected to its pulse generator (PFN) through five 15Ω cables in parallel able to hold the high voltage pulse travelling along them and giving a characteristic impedance of 3Ω . The matching of all elements of the chain is only appro-

ximate, chiefly for the magnet, which is not of the delay-line type, but pure matching is not strictly necessary to obtain good pulse shapes. The generator is a 3Ω pulse-forming-network made of 34 capacitors, each of the eleven sections having three capacitors in parallel except the first which has four symmetrically placed around the axis of the switch. Besides, each capacitor of the first section has a 6Ω carbon resistor in series and the switch has a coaxial envelope in order to obtain a field rise time as short as possible (150 ns). The switch consists of a three-stage thyratron filled with low pressure deuterium. The complete PFN is immersed in special mineral oil permitting the holding of high d.c. voltage gradient.

At the extremity of the high voltage cables, under the vacuum tank, the matching resistor of 3Ω impedance is cooled by circulating oil to remove the heat generated during fast pulsing. The full aperture magnet located in ultra-high-vacuum has a very simple structure : two horizontal plates connected together by short end pieces on either side of the beam passage, and connected to the outside feeders by a coaxial feed-through, Fig. 2. In fact an effort has been made during the design to get a good transverse homogeneity of the kick strength (1% over 8cm width) by giving a special shape to the cross-section of the plates, Fig. 3. This equipment is described in internal notes ^{1,3}), as is also the absorber block ²), the electronics ⁷), the ultra-high-vacuum tanks and their controls ⁸).

3. Operational Results

Since the first running-in test of the ISR in October 1970, The Beam Dumping system has been used in three ways : repetitive injection and dumping, manual dumping and automatic dumping.

For the first use the Beam Dumping system is triggered by a so-called M pulse in synchronism with the injection of the PS beam in the ISR, allowing the injected beam to circulate during almost the complete PS period in order to make precise measurements of the beam characteristics. The manual triggering is used at will, e.g. when the stacked beam should be eliminated at the end of physics runs. The automatic dumping works if one of the following faults occurs in the ISR: main magnet break-down, mains break-down, UHV pressure increase, sector-valve closing, tunnel access door opening and beam loss. Some of these causes influence the beam only slowly and a fairly long reaction time from the dumping system would be sufficient. But others act quickly, particularly beam losses for which loss time constants of about

5ms have been recorded. The reaction time includes the time taken to signal the fault, the electronics delay, the thyatron's anode delay and the field rise time. The last two operations can in fact be carried out in less than 1 μ s, but at present the two others are relatively long operations due to relay's slow action and the development of a fast electronics system is now actively pursued.

One can define the beam dumping efficiency as the fraction of the particles which are dumped on the absorber input face. Only during the field rise time, the kick is not enough to send the particles on the block input face but a part of these particles make a turn more in the ring and are dumped after their second passage in the pulsed magnet. Thus the efficiency is estimated to be $3.15 \mu\text{s} - 0.15 \mu\text{s} / 3.15 \mu\text{s}$ i.e. 95%. This efficiency becomes slightly lower for high energy and large beam height when some limitations due to high voltage or high repetition rate prevent all particles hitting the absorber input face.

An effort has been made to build a system with a high reliability and in fact the system has worked correctly since the first ISR tests⁴⁾, resulting in relatively low induced radioactivity around the ISR tunnel except in the Beam Dumping region. However as it is impossible to exclude the possibility of having a spontaneous discharge of the d.c. charged generators during long physics runs, resulting in a complete loss of the stacked beam, two new improvements are now developed : a resonant charging power supply⁵⁾ which has the inconvenience of a relatively long response time (6 ms) or an oversized spark-gap⁶⁾ capable of switching the four generators of one ring in parallel, but which necessitates a long development work.

4. Scraping Targets

Scraping Targets (ST), one system per ring, are required for protecting the screens of the injection kickers from the tail of the beam which is phase-displaced inwards during stacking, and for removing the low-density halos from the stack to reduce the background during colliding-beam experiments.

The Targets consist of thin tantalum scattering foils on moveable arms driven by stepping motors under electronic control. These support arms serve also as thermo-syphon water circuit for cooling and as a low-resistance electrical circuit for measuring the resistance, and hence the approximate temperature, of the tantalum foil. The mechanical movement between the components in ultra-high vacuum and the outside is made through a system of stainless-steel bellows. Each ST assembly comprises two targets whose radial motion is mechanically coupled to compensate atmospheric pressure forces. The vertical motions of the two targets are, however, completely independent. The outer and inner targets are used for scraping the corresponding radial limits of the stacked beam; either target can be used for scraping the vertical beam limit. Since the ST are located at azimuths with a large vertical betatron ampli-

tude function, protons intercepted by the tantalum foils are scattered such that beam growth occurs mainly in the vertical plane. After a few tens of traversals these protons are intercepted by the absorber block of the beam dumping system, before their radial amplitude has grown very much.

The ST are always used for high-intensity 20-bunch stacking. Since they are widely separated in azimuth from the kickers, the position of the screen "shadow" at the ST depends on closed orbit errors and must be measured, using a beam, whenever there has been an important change in operating conditions.

The scraping targets are also used for slow dumping (around 5 seconds) of a full stack, either for stack density measurements or, as happened on one occasion, in the event of a fault in the normal fast dumping system. The use of the ST for beam diagnostics is described in another paper of this Conference.*

References

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Acknowledgements

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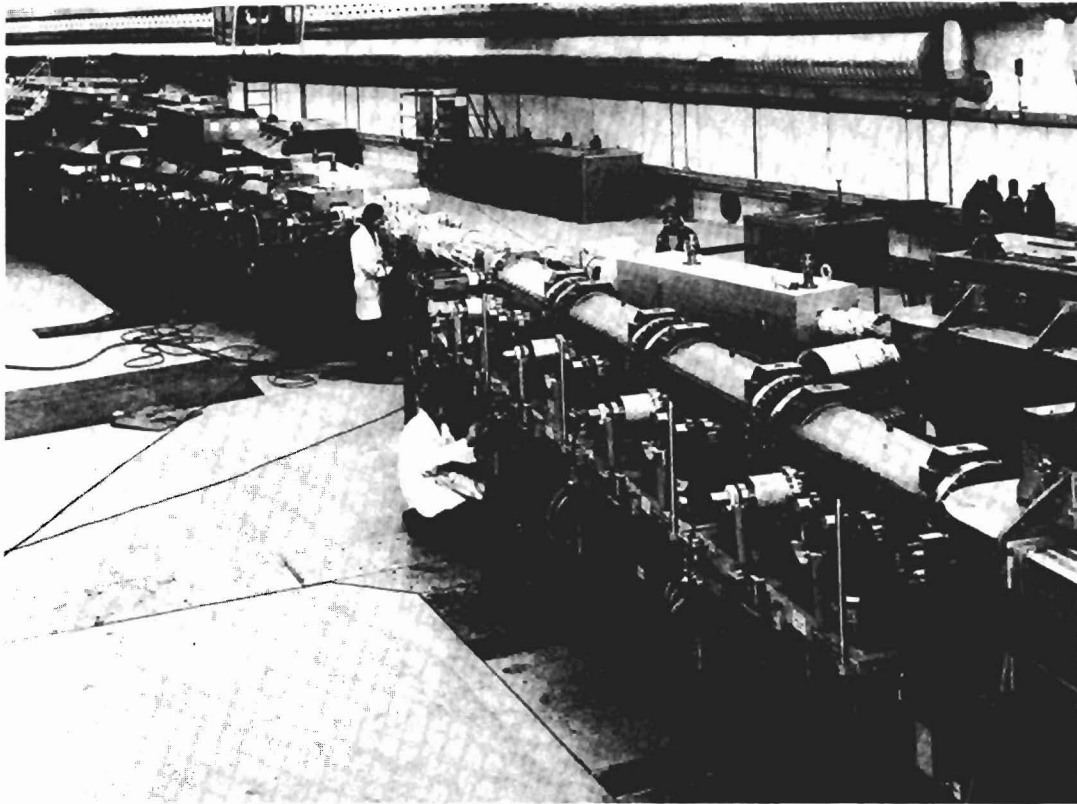


Fig. 1 The I_3 intersection region where are situated the Beam Dumping systems of the two rings

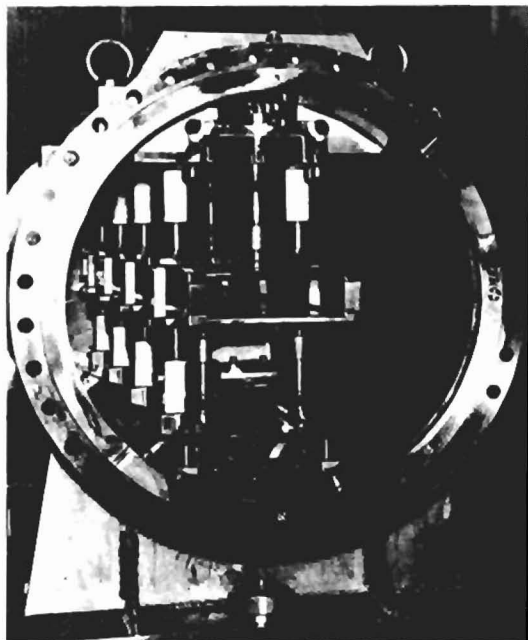


Fig. 2 The full-aperture ferrite less pulsed magnet in its tank

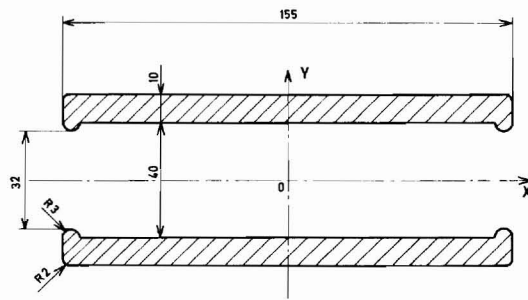
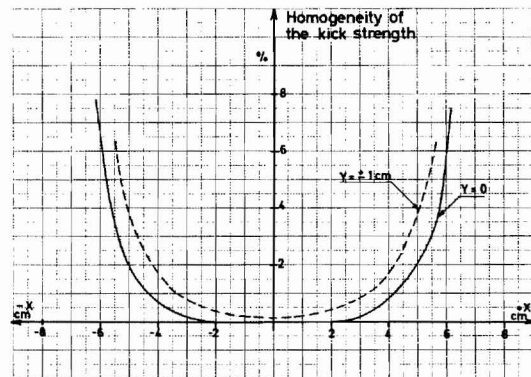


Fig. 3 The kick strength homogeneity and the magnet plate cross-section

DISCUSSION

J. P. BLEWETT: What is the configuration of the beam dump itself?

M. J. DE JONGE: Perhaps Schnuriger would answer this.

J-C. SCHNURIGER: The absorber block for beam dumping is made of stainless steel, its length is 2.5 m. At the front end of the block is a stack of titanium discs over a length of 60 cm.