Cambridge electron accelerator bypass · Der Bypass am Elektronenbeschleuniger von Cambridge

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1. Introduction

In the Cambridge electron accelerator (CEA) bypass project, the 6 GeV electron-synchrotron itself is used for accumulation and storage of counter-rotating electron and positron beams. For this purpose, several special improvements and additions to the accelerator were necessary, none of which interfere with normal use of the synchrotron in high energy physics research projects of conventional type.

The major improvement to the accelerator was an upgrading of the synchrotron vacuum system. Installation of ceramic vacuum chambers, chemical cleaning of straight section tanks and vacuum pumps and bake-out of the whole vacuum system result in reducing the average pressure by two orders of magnitude to 2×10^{-8} Torr. With such vacuum, a decay time of stored electron currents of 2 hours has been achieved.

Among the major necessary additions to the synchrotron were a damping system, a positron injector, and the bypass.

2. Damping system

The damping system, consisting mainly of two high-gradient multipole magnets mounted in two straight sections, provides damping of horizontal betatron oscillations through synchrotron radiation. A special damping system is necessary because, unlike a storage ring, a strong focusing electron synchrotron has normally a magnet lattice which results in anti-damping of horizontal betatron oscillations. With our damping system, installed and tried out successfully in 1966, storing of electrons with energies up to 3,5 GeV has been routine.

3. Positron injector

The positron injector uses the normal 130 MeV electron linear accelerator to produce positrons in a tungsten converter (Fig. 1). The positrons are then collected and focused by strong axial magnetic fields and postaccelerated in another linear accelerator to an energy of 130 MeV. Positron pulse currents up to 1 mA (with 0,2 mA within a $\pm 1\,\%$ momentum spread) are thus produced.

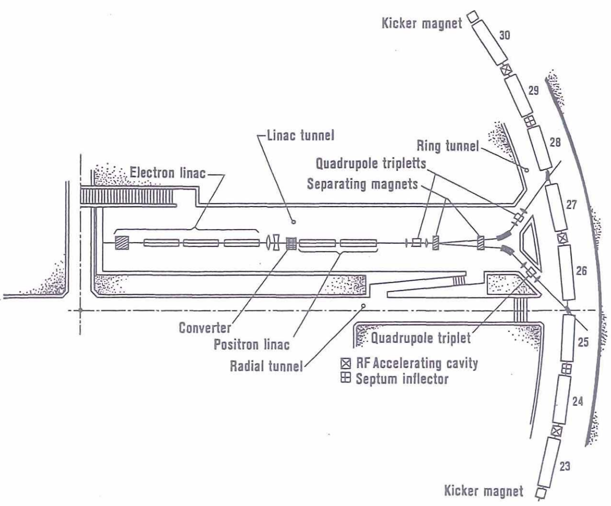

Fig. 1: Positron injection layout

Fig. 1: Anordnung zum Einschließen von Positronen

4. Bypass

The bypass is a beam-transport system consisting of 12 quadrupole lenses and eight bending magnets (Fig. 2). It bypasses approximately nine synchrotron magnets. Arranging for the stored beams to collide in the bypass instead of in the synchrotron provides several advantages: in the center of the bypass, where positron and electron beams are to collide, beam cross sections can be decreased through extra-strong focusing by more than two orders of magnitude as compared to the cross sections in the synchrotron, thereby increasing the luminosity by more than two orders of magnitude. Also the center portion of the bypass is designed for high accessibility, easily accommodating larger detection and analysis equipment at the interaction region (Fig. 2).

5. Operation

The operational sequence of preparation for a colliding beam experiment is as follows: positrons of 130 MeV energy are injected clockwise into the synchrotron. There they are accelerated to an energy of 2 GeV and then decelerated to the injection energy of 130 MeV again. During such a cycle ($^1/_{60}$ of a second) radiation damping, which occurs mainly at the top of the cycle, decreases the beam cross section enough so that new injection is possible. Positron accumulation thus takes place at a rate of 60 pulses per second, with a total fill time of about 1 minute.

The minimum energy of the synchrotron is then raised from 130 MeV to 260 MeV, the positron converter is removed, and electrons, now being accelerated by the combined electron and positron linear accelerators to energies of 260 MeV, can be injected *counterclockwise* into the synchrotron. Electrostatic fields keep electron and positron beams vertically separated in the synchrotron. After electron filling is complete, the ac component of the synchrotron magnet power is turned off and both beams are now stored at a constant energy of approximately 1 GeV. By adjusting the dc current of the synchrotron magnet the operator can change the energy to any desired value between 0,7 GeV and 3,5 GeV. After the desired energy for the colliding beam experiment has been set, fast deflecting magnets switch the beam into the bypass and then from the bypass back into the synchrotron. Lifetimes of beams in the bypass are of the order of one hour.

By the summer of 1970, all the necessary hardware had been tested and installed. In the fall of 1969, 2 GeV electron beams were, for the first time, successfully switched into the bypass. Lifetimes of 45 minutes were achieved. Tests of positron multicycle injection started at the beginning of 1970 and to date have resulted in accumulation of positron currents up to 11 mA, which is 11 % of the design value. Electron currents up to 45 mA have been accumulated in multicycle injection (45 % of the design value). Peak currents in both cases seem to be limited by single-beam instabilities.

On April 11, 1970, both beams were kept simultaneously in the synchrotron for the first time (Fig. 3). In this test the electrostatic beam separation system was not used and beam-beam interactions limited the possible currents to 5 mA.

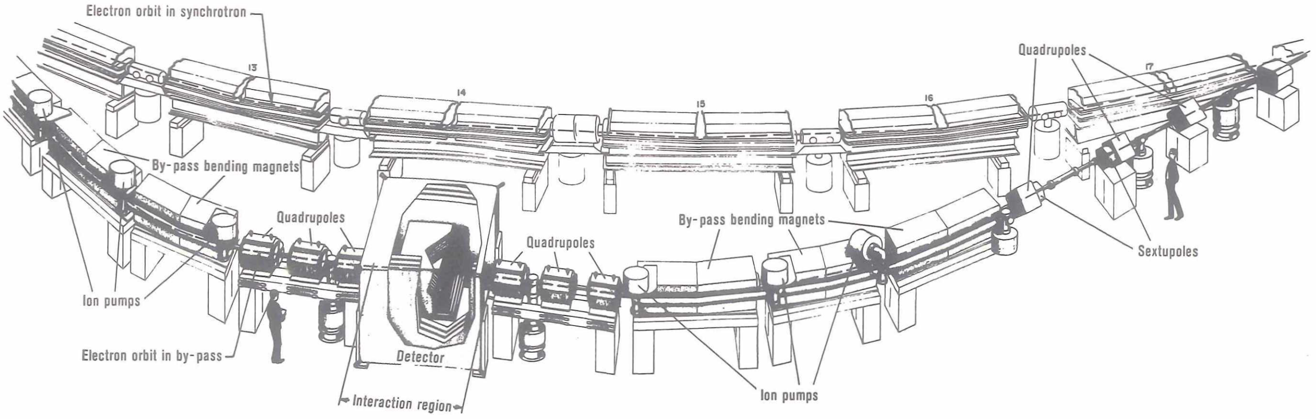

Fig. 2: Bypass, schematic

Fig. 2: Schematische Darstellung des Bypass

Fig. 3: First simultaneous storage of electron and positron beams (at 2 GeV) in the synchrotron ring

Fig. 3: Erste gleichzeitige Speicherung des Elektronen- und Positronenstrahls (bei 2 GeV) im Synchrotronring

The three television monitors in Fig. 3 show the beam cross sections as seen in three different machine straight sections. Mirrors arranged at 45° angles allow to view simultaneously the electron beam and the oppositely traveling positron beam. The beams were actually on the same path and only the optical system makes them appear at different locations. Beam cross sections appear to be different on each monitor since at any straight section one is always viewing beams in a closed and open magnet.

It is expected that during the second half of 1970 studies of single beam instabilities and beam-beam interactions will reach the point where it is possible to store large electron and positron currents simultaneously and to switch them into the bypass. At that time experimentation with colliding beams will begin: in the first experimental set-up, a large-solid-angle detector using wire spark chambers and shower counters will surround the interaction region. This non-magnetic detector is designed mainly to detect and identify electrons, muons, photons and hadrons. A magnetic detector for more detailed identification of hadron events is under construction.

The design and construction of the colliding beam facility is a major effort of the CEA laboratory, with many people collaborating. For a more detailed technical description of the bypass see [1]. Groups from Harvard University and the Massachusetts Institute of Technology are cooperating in the design and construction of the detectors.

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References

[1] Hofmann, A., R. Little, H. Mieras, J. M. Paterson, K. W. Robinson, G. A. Voss and H. Winick: The Colliding Beam Project at the Cambridge Electron Accelerator. Proc. of the Sixth International Conference on High Energy Accelerators 1967