PETRA-INJECTION-SYSTEM

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The storage ring PETRA is designed for an average circulating current of 2 x 80 mA contained in 2 x 4 bunches. That corresponds to 10^{12} particles/ bunch. The injection energy was chosen to be as high as possible for two reasons: Since the damping time of the horizontal betatron oscillations decreases with increasing energy higher injection rates are achievable and beam instabilities in lower energy regions are avoided. Therefore the 7 GeV synchrotron DESY is used as injector for PETRA. The highest injection rate is 10 Hz at this energy. Since there are only $2 \cdot 10^7$ positrons in one 2 ns-linac-bunch the filling time would be nearly 6 hours. For that reason the storage ring DORIS is used for intermediate storage of positrons. Thus 30 linac bunches every 20 ms can be used leading to a 150 times shorter filling time.

Principle of Operation

The PETRA injection system works in the following way (Fig. 1)

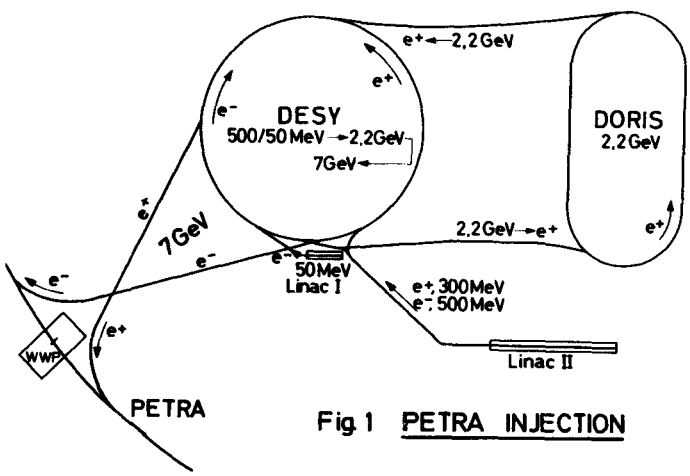


Fig 1 PETRA INJECTION

Every 20 ms a train of positron bunches separated 32 ns from each other will be accelerated in Linac II up to 300 MeV and then injected into DESY which operates with a max. magnetic field corresponding to 7,8 GeV during the injection procedure. At 2,2 GeV these bunches are transferred to DORIS and accumulated there. The two upper halves of DORIS are coupled together forming one ring, in which 30 circulating bunches will increase in charge. Before bunches reach the threshold of instability a fast kicker ejects these bunches out of DORIS one at a time. It will be reinjected into DESY, accelerated up to 7 GeV, transferred to PETRA and accumulated there. A frequency shift of max. 1,5 kHz of the DESY-DORIS-rf-system against the PETRA-rf-system allows for filling every predetermined bucket in PETRA.

Electrons will be accumulated by transferring single bunches with high charge

from Linac II after acceleration in DESY to 7 GeV without intermediate storage in DORIS.

Changes of the existing machines had to be introduced in order to use them for the PETRA-injection and new components had to be built. The main activities concentrated on the following items:

1.) Modifications of the linacs

2.) DORIS as an intermediate storage ring

3.) 7 GeV-ejection DESY

4.) Transferlines DESY-PETRA

5.) Injection components PETRA

1.) Modifications of the Linacs

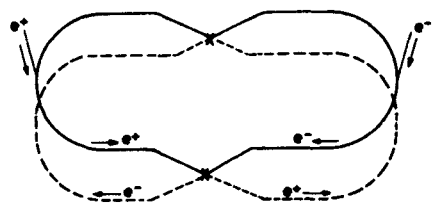
In 1975 two chopper systems were installed in Linac II: the first one is for generating a time structure of 500 or of 125 MHz, as needed for running DESY and DORIS for high energy experiments and as a prechopping device for the second chopper. With the second plate system it is possible to produce either single 2 ns-bunches or bursts of bunches separated by 32 ns from each other (ν_{rf} = 15,625 MHz). The new injection system has a better transmission than the old one, a beam current of 4 A injected into the first linac section is achieved without difficulty. Single e^--bunches with the charge of $5 \cdot 10^9$ particles are produced, injected into the synchrotron at 500 MeV and accelerated up to 7 GeV. This is enough intensity for a direct transfer of electrons Linac II-DESY-PETRA. In the first year of operation of PETRA Linac II will be the source for both kinds of particles. It would be more convenient to fill PETRA simultaneously with positrons and electrons in a pulse sharing scheme. Therefore a development program at Linac I with the aim of getting single e^--bunches with an increased intensity has been initiated.

2.) DORIS as an Intermediate Storage Ring

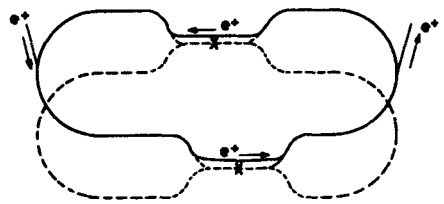
In order to use the normal e^--transfer channel between DESY and DORIS as e^+-injection path out of the storage ring the positrons have to circulate only in the upper two ring halves of DORIS. This single ring mode is achieved by changing the powering of vertical bending magnets so that the particles no longer cross the interaction points under a vertical angle but pass horizontally 3 cm above the interaction region (Fig. 2).

There are two beam bump magnets and a new fast kicker necessary for the ejection of single positron bunches out of DORIS. The slow beam bump generated by these magnets will move the stored beam with its 30 bunches into the gap of the fast kicker, which deflects one bunch over the pulse septum current sheet into the

Fig. 2



Normal $e^+ e^-$ operation of DORIS



DORIS as intermediate storage ring for PETRA injection

dc-septum, elements, which are used for the injection into DORIS as well.
The fast kicker must not excite the other 29 bunches, i.e. the total pulse length has to be smaller than 64 ns. Therefore the gap dimensions are as small as possible: 15 x 8 mm^2. The length is 20 cm and the conductors are coaxially arranged thereby shielding the ferrite from the fields of the stored beam. The resultant pulse shape is nearly triangular with a base of 50 ns and the max. deflection angle is 0,8 mrad for 2,2 GeV particles.

3.) 7 GeV Ejection DESY

The new ejection systems are convential: A beam bump generated by pulsing the back leg windings of six synchrotron magnets moves the circulating beam into the gap of a C-type kicker located at the inner side of the ring. The kicker deflects the particles into a septum magnet which bends the particles out of the synchrotron.

4.) Tranfer Lines DESY-PETRA

The new transfer channels are shown in Fig. 3. In order to make the two beam transportsystems as cheap as possible both channels are housed in simple sewer pipes of about 100 m length with no optical elements in them.
On the whole there are 17 quadrupoles with apertures of 140 and 70 mm and 13 bending magnets (DVM, M, IM) with gap heights down to 19 mm.
The 9 magnets (type M) deflect the beam by $68{,}5^{\circ}$ (e^+) and $53{,}7^{\circ}$ (e^-). The two dc-septa (type IM) produce an angle of $9{,}2^{\circ}$ each.

5.) Injection Compenents PETRA

After passing the injection magnet IM the beam enters the PETRA injection pulse septum PS by which the single bunches are bent additionally by 30 mrad. The core of this magnet is laminated steel housed in a vacuum tank. A titanium foil of 0,1 mm thickness separates the transport vacuum system (10^{-5} Torr)

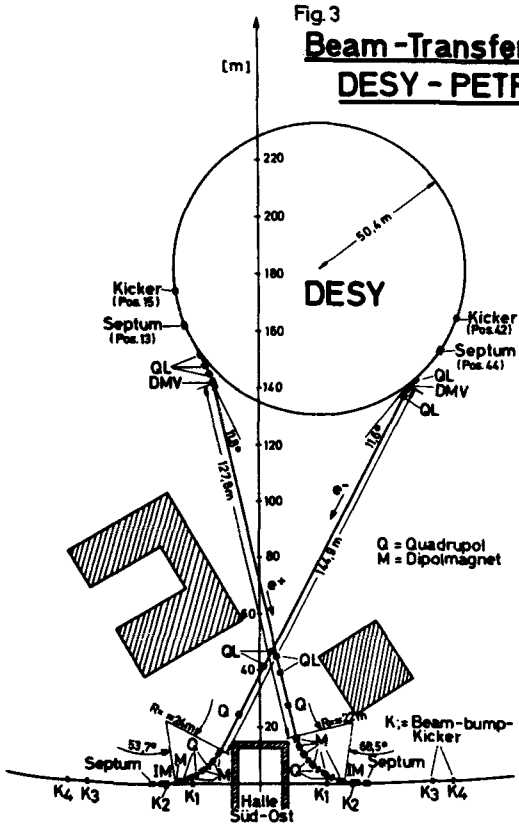


Fig. 3 Beam-Transfer DESY - PETRA

from the PETRA uh-vacuum (< 10^{-8} Torr) at the septum exit.

The PETRA injection channel is shown in Fig. 4. During each new injection of a single bunch the beam already stored is shifted close to the septum by powering of four ferrite kicker magnets. The ferrite core and the excitation coils of these magnets are outside of a metallized ceramic vacuum chamber. The thickness of the metallization is a compromise between two contradicting requirements: First the higher harmonics of the beam current spectra must find the same geometry and conductivity of the wall as in the normal beam pipe. On the other hand the coating must allow the pulsed kicker field to penetrate the vacuum chamber without attenuation and corresponding power losses. The result is a 1,5 µ thick coating of titanium. The max. power losses inside the metallization by synchrotron radiation, beam current and kicker field add up to 350 W.

Status of the PETRA Injection System

In January of this year all elements for the 7 GeV ejection were installed in the synchrotron ring. Soon afterwards the e^--ejection was tested: electrons from Linac I were accelerated up to 7 GeV and kicked out into a short part of the transport channel. The system works fine, the transmission is 100 % and the

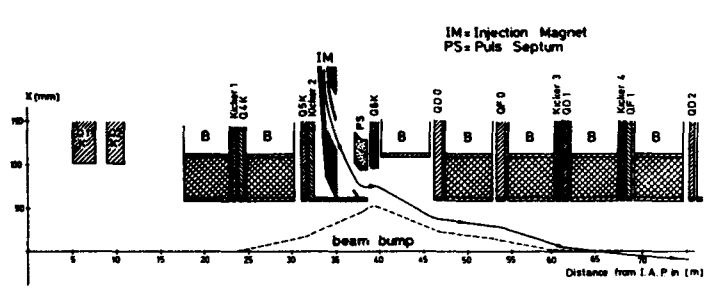


Fig. 4 PETRA Injection Channel

beam seen on a screen monitor located one synchrotron sector downstream from the septum has the expected dimensions: 10 x 1 mm^2. Full installation of the e^--transfer channel is scheduled for August 77.

The positron transfer channel between DESY and PETRA was completed April 77. Positrons were injected several times from Linac II, accelerated to energies between 5 and 7 GeV, ejected and guided through the channel. The transmission was 100 % at 5 GeV, at 7 GeV a loss of 20 % occurred due to the large emittance (8 π mm · mrad) of the Linac beam at 300 MeV and the radiation antidamping of the horizontal betatron oscillations in DESY. Since the emittance of the beam in DORIS is only 0,2 π mm · mrad at 2,2 GeV, the losses in the transfer channel were, as measured later, negligible when positron bunches were taken from DORIS.

In April DORIS was operated for the first time in the single ring mode. After correcting and aligning the closed orbit in the machine acceptances of $A_x \geq 40$ mm mrad and $A_z \leq 10$ mm mrad were achieved. Correcting the chromaticity by sextupoles led to an increase of the storable charge from 0,25 mA/bunch to 5 mA/bunch, thus making it possible to eject single bunches with a smaller rate than 10 Hz.

In this first attempt the injection rep. rate was 25 Hz and single bunches were ejected with 2,5 Hz one after the other, the fast kicker timing advancing 32 ns from one shot to the next. The particles were reinjected into DESY, accelerated up to the full energy of 7 GeV and ejected into the transfer channel to PETRA. $2 \cdot 10^9$ particles/bunch were obtained which is 100 times more than could be delivered directly from Linac II.

In a later run the injection rep. rate was raised to 50 Hz, the ejection rate to 10 Hz, and the single bunches were already transferred via DESY through the first octant of PETRA.