DESY III, THE NEW PROTON INJECTOR FOR HERA

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Summary

The design of a 7.5 GeV/c proton synchrotron, DESY III, which will form part of the injector chain for HERA /1/ is described. Features of the lattice and brief details of sub-systems are presented. A selection of parameters and expected time schedule for the accelerator which is at present under construction at the DESY laboratory, Hamburg, are given.

Introduction

The synchrotron is intended to serve solely as part of the HERA proton injector chain. Injection is from a 50 MeV H^- linac /2/ and after acceleration to 7.5 GeV/c the beam is extracted into PETRA. Since the overall filling time of HERA is dominated by the necessarily slow acceleration in PETRA there is no need for the synchrotron to be fast cycling. The RF harmonic no. is conveniently chosen so that the final HERA bunch spacing, 28.8 m, is established in DESY III and beam accumulation in the subsequent rings is by box-car stacking. With the replacement of the old DESY-synchrotron there is a strong motivation to make use of the available combined function magnets.

Lattice Design

The old DESY-synchrotron consists of 24 symettric FODO cells where F, D refer to combined function focussing, defocussing magnets respectively however, the straights are too short to install the injection, RF and extraction systems for proton operation. Further, if the transition energy were to remain within the operating energy, a sophisticated γ_t-jump scheme would have to be installed to preserve the injected beam brightness. The chosen magnet lattice provides γ_t above γ at extraction together with long straights. The superperiod structure and envelope functions are illustrated in Fig. 1. The complete ring consists of 8 such superperiods within which the magnets are grouped together and additional quadrupoles are inserted to maintain low dispersion in the magnets and hence a high γ_t. There are 4 such independently powered quadrupoles per superperiod which allows some flexibility in the choice of working point (betatron tunes) whilst maintaining the required γ_t. There are a total of 8 long straight sections each providing > 5 m effective free space.

Standard considerations of avoiding low order systematic non-linear transverse resonances in an 8-fold periodic structure govern the choice of working point which is set at $Q_x = 5.90$ and $Q_z = 4.82$. Fig. 2 is a diagram of Q_z versus Q_z in the region of the chosen working point showing all possible 3rd and 4th order resonances. The shaded area indicates the expected spread in betatron tunes within the beam due to transverse space charge forces at injection (assuming a parabolic transverse beam distribution). It is planned to equip each straight section with a variety of strategically placed non-linear elements to allow compensation of those resonances which intersect the working region. Initially only DC correction is foreseen however, if necessary, programmed compensation up to 1.5 GeV/c may be provided. Above this momentum, space charge defocussing is small enough to ensure that the working area is clear of intersecting resonance lines. It is not planned to install a sextupole

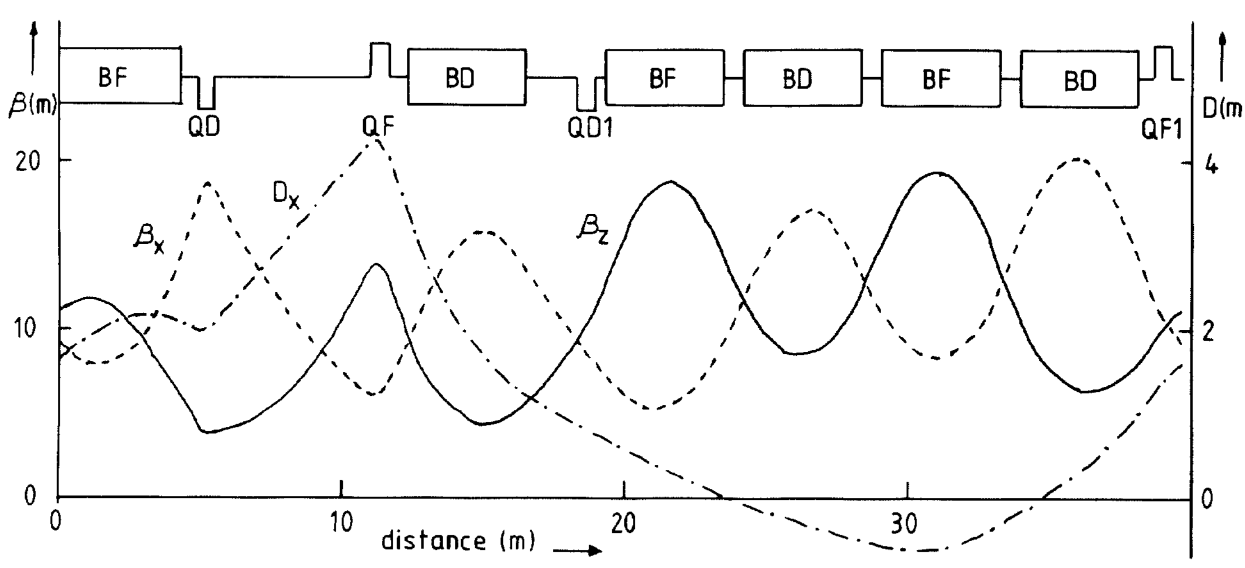

Fig. 1 - Lattice Functions

system to correct the natural chromaticity since firstly, for a ring operating below transition, the lowest mode of the transverse head-tail instability is stable and secondly the chromatic Q-spread is small, being $\pm$ 0.01 at injection and further reduced to $\pm$ 6 x 10^{-3} at full energy.

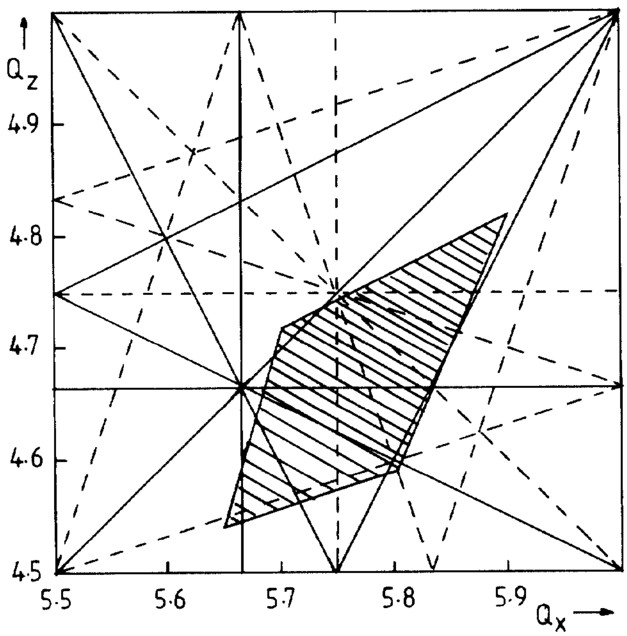

Fig. 2 - Tune Diagram

A total of 32 inductive pick-up stations are installed to give beam position information. Vertical orbit deviations will be corrected at injection by powering up to 32 discrete correction coils each of which is capable of steering the beam over the complete aperture. Horizontal correction will be made using the existing backleg windings of each F-magnet together with 8 additional discrete coils. The high energy orbit will be corrected, if needed, by appropriately displacing some of the quadrupoles. It is expected that this procedure will not need to be used more than once or twice per year.

Fig. 3 is a plan view of the synchrotron hall showing both DESY III and DESY II /3/. The azimuthal orientation of the ring has been chosen so that where possible the beamlines to and from DESY II cross the proton ring in magnet free regions. Where this cannot be achieved the beams cross in D-magnets which have enough vertical space between the excitation coils so that the back-leg of the C-shaped yoke may be drilled through and special interconnecting vacuum chambers can be installed.

Parameter List

Mean Radius	50.42	m
Cycle Time	3.6	s
Total No. of Protons	1.125×10^{12}	
Betatron Tune (Q_x/Q_z)	5.90/4.82	
Gamma (transition)	8.77	
Chromaticity (ξ_x/ξ_z)	-6.14/-5.82	
Acceleration Rate	5.0	GeV/c/s
Stable Phase	17.1	Deg.
RF Voltage	18	kV
Ejection Momentum	7.5	GeV/c
Bunch Length (Ejection)	2.34	m
$\Delta p/p$ at Ejection	$\pm$ 9.8×10^{-4}	

Major Subsystems

The 48 combined function magnets, each 4.15 m long, are taken over from DESY. The gap heights on the equilibrium radius are 56 mm and 88 mm for the F and D respectively. At the time of this conference a program of field measurements, aimed particularly at finding the variation of multipole content from magnet to magnet, is underway. The quadrupoles of length 0.58 m with an aperture inscribed circle radius of 50 mm are a modification of the type used in DESY II. All have been measured and exhibit a tolerable multipole content.

The single RF cavity is one of the spare PS units from CERN consisting of two quarter wavelength ferrite loaded resonators each with one ceramic gap. The power amplifier, capable of delivering up to 40 kW, is housed in the support structure with the output tetrode being directly coupled to the cavity. The maximum peak voltage provided is 20 kV which, with the harmonic no. chosen as 11 and the given longitudinal emittance from the linac, limits the initial acceleration rate at injection energy to be $\le$ 5 GeV/c/s. Maintaining the corresponding field rise throughout acceleration together with injection and ejection platforms and identical field fall leads to the cycle time of 3.6 s. A high current regulated power supply capable of providing up to 3000 A at 30 V is used to tune the cavity over the required frequency range (3.3 MHz to 10.3 MHz).

The stainless steel vacuum system has chambers of two distinct cross-sections. In the F-magnet an elliptical chamber of 1.5 mm wall thickness having inner dimensions of 83 mm wide and 51 mm high is used. In the D-magnets and elsewhere a circular cross-section of 84 mm inner diameter with 1 mm thick wall is used. Conflat-Systems flanges are used to connect chambers together and where this involves different types a transition is used to taper the abrupt step thus minimising the longitudinal impedance presented to the beam. The aperture provided corresponds to a linear betatron acceptance of twice the transverse emittance delivered by the linac. Calculation of the expected eddy currents have shown the losses to be negligible and the influence on the field, particularly the sextupole content, to be entirely within tolerable limits. The pumping system installed will maintain a pressure of 10^{-8} mbar.

H^- ions from the linac are injected, from the ring outside, in a straight section on to a thin (30µg cm^{-2}) Alumina foil. This is situated between 4 ferrite bump magnets which displace the equilibrium orbit locally outwards by 60 mm so that it passes through the stripping foil. Some 98% of the incoming beam is converted to protons so that, assuming a linac current of ∿10 mA together with 100% RF trapping, 6 turns must be injected to produce the required 1.1 x 10^{-11} protons per bunch. The bumper power supply, which delivers 6000 A at 2 kV, may be set to give a 35 µs flat ($\lesssim$ 1%) pulse length allowing up to ten turns to be injected. The pulser fall time is specified to be < 30 µs so that the transverse emittance growth produced by multiple foil traversals < 10%. The complete system is housed in its own vacuum tank and a remote foil changer is installed containing 5 spare foils.

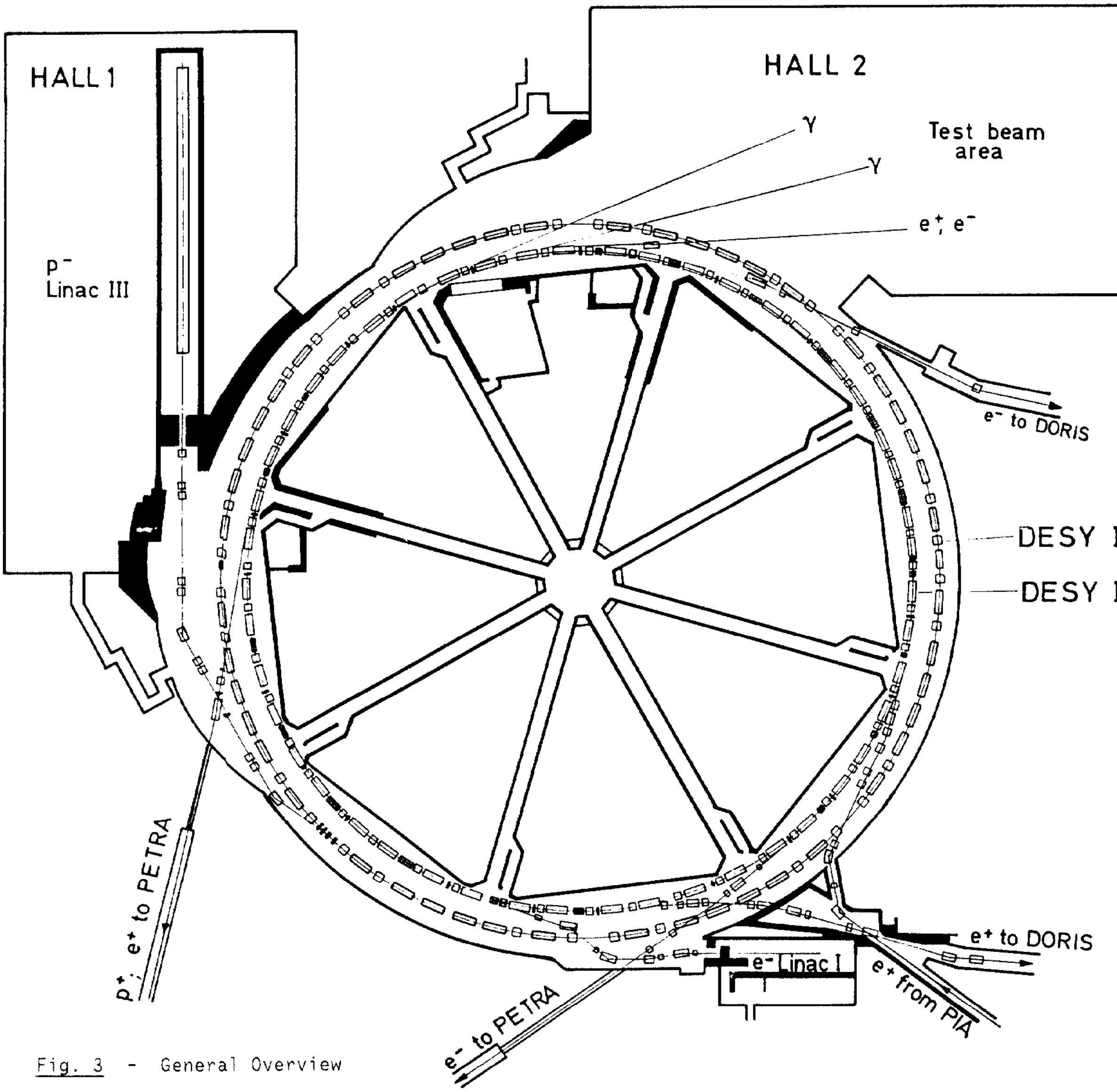

Fig. 3 - General Overview

The beam is ejected horizontally in a single turn by means of fast kickers and a pulsed septum magnet and transferred into matched RF buckets in PETRA. The beam transport line is that used to transfer e^+ from DESY II. The circulating beam is displaced outwards locally towards the septum by means of a slow bump generated by powering the back-leg windings in some F-magnets. The final jump across the septum is provided by two ferrite kicker systems, one situated in a medium straight immediately upstream of the extraction straight and the other in the preceding long straight. Each kicker system consists of 2 C-shaped ferrite magnets fed by a pulse forming network giving a current of 1.75 kA with a rise time of ∿140 ns and a pulse duration of 1 µs. Since the separation between tail and head of consecutive bunches is 90 ns this means that one out of the 11 circulating bunches is discarded.

Signals from the diagnostic systems, such as the position monitors, are transmitted via the standard DESY PADAC/SEDAC system to a console sited in the main accelerator complex control room. Much of the applications software for status display and operator intervention may be taken over from that developed for DESY II.

Time Schedule

At the time of this report (March 1987) the original DESY synchrotron has been removed from the hall and all preparatory work, such as drilling the fixing holes for magnet supports, has been completed. Installations of the components will begin in May 1987 and continue for 6 months with a break of about 6 weeks for a scheduled running period of DESY II. Testing of the complete ring will commence in November 1987 and commissioning with beam is expected to start at the beginning of 1988.

References

/1/ R.Kose "Status of the HERA Project" contribution to this conference
/2/ U.Timm (Ed) "Project study for the 50 MeV HERA LINAC as H^- injector for DESY III" DESY HERA 84-12
/3/ G.Hemmie "Status of the DESY II Project" contribution to this conference.