STATUS OF THE HERA PROJECT

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Introduction

In this article I describe the current status of HERA, an electron-proton colliding beam facility, which is being designed for construction at DESY in Hamburg. The HERA-Project was presented for the first time in a paper by B. Wiik at the 11th International Conference on High-Energy Accelerators[1]. That report was based to a large extent on a detailed study by a group formed by the European Committee for Future Accelerators (ECFA)[2]. Work at DESY in collaboration with many other European laboratories eventually resulted in a formal proposal[3] which was submitted to the German authorities and has been the basis for workshops[4,5] and discussions with potential foreign contributors.

During the last two years some design features and some parameters have changed. The following is an up-date of the basic lay-out and the design parameters. Most of the work since 1981 has concentrated on the fields of polarization, leading to new concepts for spin rotators and interaction region lay-outs; on injection, which now includes a new injector synchrotron; on the development of superconducting magnets, and on the preparation of the civil engineering.

This report will concentrate on the above mentioned subjects. We are now hopeful that authorization might be forthcoming at the end of 1983. The present status of the authorization procedure and our revised schedules will be described.

Basic Lay-out and Design Parameters

In the "Hadron Electron Ring Accelerator" (HERA) 820 GeV protons will be brought to collision with 30 GeV electrons. The storage ring for the protons uses superconducting magnets (4.53 T). The electron ring on the other hand is quite conventional. Both storage rings are arranged on top of each other in a deep underground ring tunnel with a circumference of 6336 m. The two beams are brought to collision in four long straight sections by making them cross in the horizontal plane at an angle of 20 mrad. Both beams will be contained in 210 bunches. Average beam currents will be as high as 58 mA in the electron ring and 480 mA in the proton ring.

The electrons will be transversely polarized due to the Sokolov-Ternov effect[6]. The build-up time for the polarization is 20 minutes at 30 GeV electron energy. In the straight sections near the interaction points vertical and horizontal bending magnets will turn the electron spin around so that at the interaction points it is parallel or antiparallel to the beam direction.

The four interaction points will be at the center of 4 large particle detectors, housed in four large underground halls together with machine and experimental control rooms, and all auxiliary equipment.

Electrons will be injected into the HERA electron ring at an energy of 14 GeV from the PETRA storage ring. Protons will be preaccelerated to an energy of 50 MeV in a new proton linear accelerator located in one of the DESY experimental halls. Protons will then be accelerated to an energy of 8 GeV in the DESY synchrotron which by that time will be dedicated to proton acceleration. A new electron synchrotron - also in the DESY-tunnel - is currently under construction and will preaccelerate electrons to 9 GeV energy. After an acceleration to an energy of 8 GeV in DESY, protons will be injected into PETRA. A special beam optics with rather weak focusing will allow acceleration of protons in PETRA up to the HERA injection energy of 40 GeV. In HERA the protons will finally be accelerated from 40 to 820 GeV and electrons from 14 to 30 GeV.

A powerful rf-system at 208 MHz will keep the protons in HERA tightly bunched and assure long proton life times. The electron ring of HERA on the other hand will make use of the large rf-system currently in use in PETRA. At present there are 16 klystrons installed in PETRA with a total rf-power of more than 10 MW and 120 five and seven cell accelerating cavities. 87 % of those transmitters and cavities will be relocated. This will leave PETRA with a 14 GeV electron capability and allow energies up to 30 GeV in HERA.

Table 1

General Parameters

	p - ring		e - ring	units
Energy	820		30	GeV
(Energy range)	(200 - 800)		(10 - 30)	GeV
Circumference		6336		m
Number of interaction points		4		
Length of each straight section		360		m
Magnetic bending field	4.53		0.1849	T
Injection energy	40		14	GeV
Rf - frequency	208.189		499.667	MHz
Max circumferential volts	25		165	MV
Circulating current	480		58	mA
Number of bunches	210		210	
Beta functions at interaction points β_x/β_z	3/0.3		3/0.15	m
Beam size at interaction points	0.12 (0.91)*/0.027		0.22/0.013	mm
Crossing angle (total)		20		mrad
Tune shift $\Delta Q_x/\Delta Q_z$	0.0006/0.0009		0.008/0.014	
Luminosity		0.6×10^{32}		$cm^{-2}s^{-1}$
Free space for experiments		15		m
Polarization time	∞		20	min

*in brackets: the effective width which is larger due to the bunch length and crossing angle

Table 1 shows an up-date of the most important HERA parameters. Most of the currently envisaged technical solutions, except for those mentioned in the next chapters, are still quite close to those described in[1,2,3]. The reader may therefore refer to these more detailed descriptions.

Polarization, Spin Rotators and Interaction Regions

The longitudinal polarization of the electrons at the interaction points is a very important feature of experimentation with HERA. Alternate use of positive and negative helicity will allow investigation of spin dependent behaviour of the charged and neutral weak interaction currents. Special attention has been given to this aspect by measuring the degree of polarization obtainable in PETRA, beam-beam-depolarization effects in PETRA and by testing methods of compensating depolarizing resonances[7,8]. In PETRA the observed polarization of the stored electron beam has been close to the theoretical limit (92 %). Beam-Beam interaction was found to have a depolarizing effect, but only at space charge parameters ΔQ larger than 0.02. These ΔQ-values are larger than those assumed in the HERA-proposal (0.014). By empirically compensating harmonics of the vertical orbit distortions which are close to the number of spin precessions per revolu-

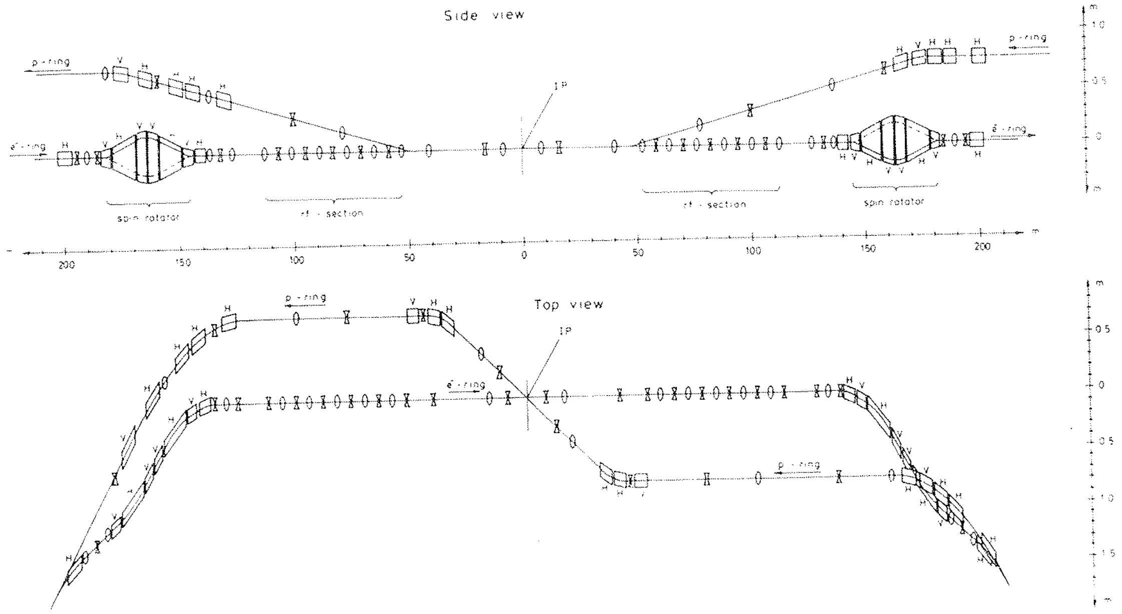

Fig. 1 HERA straight section design with spin rotators (note the different scales in longitudinal and transverse directions

tion, large polarization values can be produced in a reliable way. Particular attention is given to the depolarizing effects produced by various spin rotator designs. An optics solution for the HERA straight section has been worked out which includes a spin rotator and which is "spin transparent", i.e. in which the depolarizing effects in the straight section have been minimized[9]. However, that particular spin rotator scheme has the disadvantage that vertical bending magnets must be physically moved, whenever the helicity of the electrons is to be changed. A new type of spin rotator has been invented[10] which requires only maximum orbit changes of less than 34 cm in a very limited region at the end of the straight sections. Such orbit changes can be accommodated in special wide aperture magnets so that for a change in electron helicity only the polarities of certain magnets need to be changed. Fig. 1 shows the present straight section lay-out and the presently favoured solution for the spin rotators.

Injection

Fig. 2 shows the new pre-accelerator lay-out. The injector synchrotron DESY II[11] will assume the task of accelerating single bunches of electrons and positrons for use in the DORIS storage ring and in PETRA where they will be further accelerated to 14 GeV before injection into HERA. A 50 MeV protron linac will be built and installed in one of the DESY experimental halls. It will inject pulse trains of protons into the rebuilt DESY I synchrotron. The rebuilding of this synchrotron (DESY I becomes DESY III) includes a new all-metal vacuum system, removal of the present electron accelerating cavities, installation of a proton rf-system and a new magnet powering system which will take protons up to an energy of 8 GeV in a two second sawtooth cycle.

Intermediate acceleration of protons in PETRA to an energy of 40 GeV will be facilitated by a proton acceleration rf-system in one of the PETRA halls. The PETRA bending magnets are strong enough for proton acceleration up to 45 GeV. But the focusing quadrupoles will be much weaker at 45 GeV than at the present maximum of 23 GeV. However, for proton acceleration this weaker focusing is desirable in order to push the transition energy of PETRA down below the injection energy of 8 GeV. Protons will go through a special straight section arrangement in PETRA which by-passes all remaining cavities, and the interaction of large proton currents with the high impedance electron acceleration system is thereby avoided.

In order to fill the HERA rings, PETRA must make 3 acceleration cycles with protons and three with electrons. In each PETRA cycle 70 bunches are accelerated. Each proton acceleration cycle in PETRA requires 24 filling cycles from DESY III, each electron accelerating cycle in PETRA requires 70 single bunch acceleration cycles from DESY II. The total time for filling both HERA rings is estimated to be 20 minutes. Subsequent acceleration in the two HERA rings will take an additional 3 minutes.

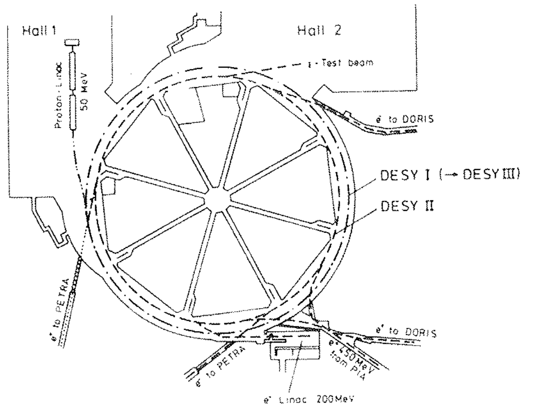

Fig. 2 The 9 GeV DESY II pre-accelerator for electrons and the 8 GeV DESY I accelerator for protrons together with the 50 MeV proton linac

The Superconducting Magnet Program

The proton storage ring of HERA needs 656 superconducting bending magnets, each 6.51 m long with an inner coil aperture of 75 mm. There are also 304 quadrupoles required and a large number of dipole, quadrupole, sextupole and octupole corrections, all built with superconducting coils.

Bending magnets are at present being developed along two different lines: A bending magnet of a design similar to that at Fermilab (Fig. 3a) is being developed at DESY. The magnet steel is at room temperature while the vacuum chamber is at the temperature of liquid helium. The main differences between this magnet and the Tevatron magnet are the aluminium coil collar (vs. steel collar), a larger cross section for the helium flow (because of the larger refrigerator spacing in HERA) and a different support system for the inner coil collar. Magnet sections of one meter length have been built and tested and fulfilled the specifications (field strength and field quality) in every respect[12]. Three full length magnets are close to completion. These magnets have been built by using all the tools and gadgets, which have been developed for later mass production.

A second type of bending magnet with cold iron (Fig. 3b) has been ordered from industry. These magnets use the same type of Rutherford cable, as the warm iron magnet. They should have a slight cost advantage over the warm iron magnet. The first full length magnet is to be delivered in November of 1983. Two more magnets will be tested in spring of 1984.

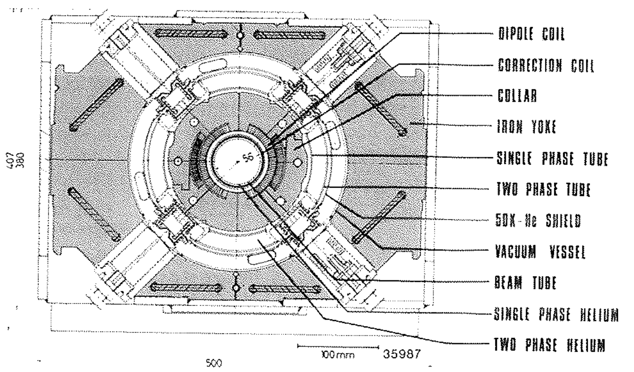

Fig. 3a The HERA warm iron magnet which is being developed at DESY

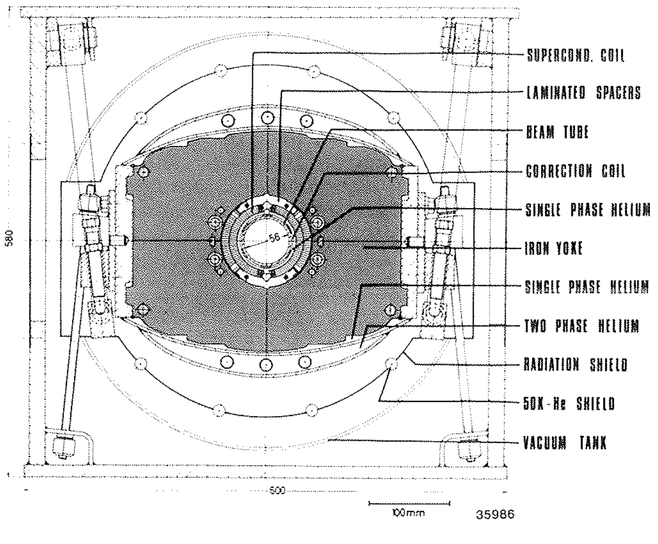

Fig. 3b The HERA cold iron magnet which is being developed by industry

In 1984 twelve more magnets of each type will be built and tested in a string resembling the final tunnel installation. Which of the two types will eventually be adopted is to be decided at the beginning of 1985.

Two HERA quadrupole magnets have been built at the Saclay laboratory and found to be acceptable. Currents in these quadrupoles reached short sample values and the generated fields comfortably exceed those required for 820 GeV operation. Relative field deviations are smaller than 2×10^{-4} up to radii of 25 mm.

Correction fields will be produced by superconducting wires wound on the cold vacuum chamber (quadrupole and sextupole corrections) and by special correction coil packages (dipole and octupole corrections). Tests of those correction coils which are inside the bending magnets and are wound on the vacuum chamber have been entirely satisfactory. (The coils have been procured for the HERA-project by the NIKHEF laboratory in Amsterdam).

Status of the Project

In February 1983 the HERA project received conditional authorization from the two German funding agencies which support the DESY laboratory, the Federal Government and the State Government of Hamburg. Both agencies are prepared to fund the HERA project in 1984 and the following years, if certain conditions are met. The most important of these conditions is a "significant participation" of other countries in the construction of HERA in order to reduce the funding requirements from the German authorities. Letters affirming an interest in such a participation have been received, and there is a good possibility that a final authorization may be forthcoming toward the end of 1983.

Preparations for the start of the construction of tunnel and experimental halls have proceeded well, so that after final authorization this work could commence at the beginning of 1984. Provided enough funds are made available at the time when needed, completion of the project is expected in 1989 and experimentation could start in 1990.

Acknowledgements

This status report describes the work of many engineers and scientists from DESY and other laboratories most of whose names are given in[2,3]. We at DESY are particularly grateful for the enthusiastic participation of our colleagues from other institutions.

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