STATUS OF THE HERA-PROJECT

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Abstract

The HERA 30 GeV electron (or positron) on 820 GeV proton collider project was authorized in 1984. In this project the beams will collide head-on and spin rotators serve to produce longitudinal electron beam polarization at the interaction points.

The civil engineering on the underground part of the 4 large experimental halls is complete and 75 % of the 6.3 km long ring tunnel has been drilled.

All electron ring magnets are being mass produced and measurements show very acceptable field quality.

All superconducting quadrupole and half of the 9 m long hybrid dipole magnets for the proton ring have been ordered. With prototype hybrid magnets, which have been built in collaboration with industry, excellent field quality and quench current limits comfortably above the design current have been achieved.

A 20 kW (4.4 k) helium refrigerator plant is close to completion.

A new 50 MeV H^- linac is under construction. The H^- source and an accelerating rf-quadrupole is already working. The construction of DESY III, the new 7.5 GeV proton preaccelerator synchrotron has been started. DESY II, the new electron/positron synchrotron, is being commissioned and has accelerated intense beams up to 7 GeV. PETRA has been converted to accelerate electrons or positrons to 14 GeV. In a second step, the acceleration of protons to 40 GeV will be made possible.

Introduction

The HERA project has been described on several occasions [1,2,3,4,5]. In the following an updated brief description of the present layout and status of the project is presented. Some basic parameters are listed in Tab. 1.

The HERA electron and proton storage rings will be installed on top of each other in a 6.3 km long ring tunnel [Fig. 1]. 30 GeV electrons or positrons will collide head-on with 820 GeV protons in 3 of 4 straight sections [5].

In contrast to previous proposals the head-on collision geometry has been chosen in order to avoid synchrobetatron resonances which can be generated in beams with non zero crossing angle [6]. Electrons (or positrons) coming from the interaction point (IP) have to be separated horizontally from the proton (p) beam [Fig. 2]. This is done using dipole magnets and quadrupole magnets in a focussing triplet which are displaced off the electron (e) orbit in such a way that they work as combined function magnets and bend the e-beam by 10 mrad. Synchrotron radiation background produced in the long (13 m) and weak separator field can be kept below tolerable limits for the experiments [5]. After separation, the e-beam passes through 1 of 6 rf-cavity sections each of which accomodate 14 rf-cavities.

It is foreseen to have a longitudinally polarized e-beam at the IP's. Spin minirotators at the ends of the straight sections turn the spin from the transverse into the longitudinal direction and back again before the e-beam enters the regular magnet lattice in the arc [7].

Protons coming from the IP will first see the fields in the e-p separator and then the fields in a focussing doublet which is composed of half quadrupole and conventional quadrupole magnets. Then the p-beam is bent vertically away from the e-ring plane. Up to here all p-magnets are normal conducting.

At 115 m away from the IP the p-beam enters the superconducting magnet lattice. After passing through 4 modified half cells the p-beam is bent vertically into the p-ring plane and the regular superconducting magnet lattice. Here the p-beam is 0.81 m above the e-beam.

In HERA stage I only 2 experiments (H1 and ZEUS) will be in place. It has therefore been decided to have a special straight section West without interaction region and spin rotators. In this straight section the beams pass through normal conducting regular FODO channels in both rings. The lattice has been optimized to simplify injection and p-beam abort systems. The later conversion to an experimental straight section is possible.

Status of the HERA-Project (Feb. 1987)

Civil Engineering

75 % of the 6336 m long tunnel has been drilled. A rate of 100 m tunnel construction per week has been achieved. Two of the 4 underground experimental halls (South and West) have been completed including the surface buildings. The subterranian part of the other 2 halls is finished. The halls South and West and half of the tunnel have been turned over for component installation. The service installations in the first tunnel quadrant (South-West) are fairly well advanced and first e-ring magnets have been installed for test purposes.

The proton injection tunnel between PETRA and HERA has been completed. Work on the electron injection tunnel is under way.

Normal Conducting Magnets

All e-ring magnets are being massproduced. 25 % of the 400 dipole, 50 % of the 580 quadrupole and 25 % of the 400 sextupole magnets and 35 % of the 600 steering coils have been delivered. The e-ring magnets in the arcs are preassembled in modular units of 11.7 m long half cells [9]. Each unit contains a 9 m long dipole, a quadrupole, a sextupole magnet, a steering coil, a vacuum chamber with beam position monitor and pumps, bus bars, some pipes and hoses for cooling water distribution, etc... The unit with prealigned magnets is supported at the quadrupole while the opposite end rests on the previous module. This concept simplifies the installation and alignment work in the tunnel. The assembly of the magnet modules has been started [Fig. 3 and 5].

A sample of the delivered magnets has been measured and shows very acceptable field quality. Multipole components higher than sextupoles contribute only

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1×10^{-4} to the dipole and 4×10^{-4} to the quadrupole field at the bore radius.

Special bending magnets (56 pieces, 9 types) with larger apertures than in the arc are needed in the straight sections and in the spin rotators. All these magnets have been ordered.

In the p-ring normal conducting magnets will be used in part of the straight sections. Most of these magnets (136 pieces, 9 types) have been ordered.

In the e/p-injection channels 27/37 dipole, 18/19 quadrupole magnets and 90 steering coils will be needed. The magnets for the p-channel have been delivered and the installation in the channel is almost complete.

Vacuum System

The standard e-ring vacuum chamber with 80 x 40 mm beam space will be constructed from extruded copper profiles, which will be up to 9 m long. Copper has been chosen to absorb 90 % of the synchrotron radiation power in the 4 mm thick chamber walls. In the dipole as well as in the quadrupole magnets the chambers contain extra channels for distributed ion sputter pumps which will maintain a vacuum pressure of $\leq 10^{-9}$ mbar. At present the copper profiles are being produced and machined and prepared for brazing in a 15 m long oven. Test brazings of short pieces have been sucessful. Great care has been taken to produce a very smooth chamber system with small longitudinal and transverse impedances as seen by the beam. The steps in the transition pieces, which are under production, are smaller than 1 mm. The vacuum system for the straight sections in the e-ring is under design. 60 % of this system can be made using standard chamber profiles and components. The vacuum system in the warm part of the p-ring will be made of stainless steel and is being designed. In the cold part of the p-ring the beam pipe is part of the cryostat [8]. 400 pipes have been delivered and 100 pipes are ready for shipment.

The Superconducting Magnet Program [10,11]

The p-ring dipole magnet has a 9m long superconducting coil which is clamped with laminated aluminium collars and surrounded by a laminated cold iron flux return [Fig. 4]. This so-called "hybrid magnet" combines some of the advantages of the Tevatron type warm iron magnets (collared coil, small saturation in flux return) with those of the CBA type cold iron magnets (small heat leakage, quench protection with cold diodes). Some 6 m long units of the latter two magnet types had been built and tested before the HERA project was approved in 1984. Meanwhile 5 fullsize "hybrid magnets" have been built in cooperation with industry. The magnets showed very acceptable field quality ($\Delta B/B \leq 1 \times 10^{-4}$ within the useful aperture of 50 mm). Without any training, the magnets could be excited to quench current levels which are comfortably above the design current of 5026 A which corresponds to 820 GeV. Recently a current of 7605 A was achieved at 3.41 k. Even at this field level the cold flux return which contributes 20 % of the field at the beam does not show significant saturation effects.

6 m long superconducting quadrupole and sextupole correction coils are wound directly on the cold beam pipe. These coils are used for tuning and for correction of persistant sextupole and chromatic effects.

After some improvements on the magnet suspension system and on the superinsulation a very small heat leakage of 5 W at 4.6 k and 23 W at 80 k (shield tempeture) was achieved.

The quench protection system which makes use of cold switching diodes and quench heaters is described in a special paper [12].

Half of the 422 superconducting dipole magnets are being built in Italy and financed by the Italian government as part of the international collaboration on HERA. Tools for the magnet production have been built and the first coils have been wound and collared. Tenders for the second half of the dipole magnets have been received from German companies. The quadrupole and sextupole correctors and superferric dipole steering coils which are housed in the quadrupole cryostat are being built and financed in the Netherlands. 40 quadrupole/sextupole coils and 25 superferric steering coilds have been delivered. The quadrupole/sextupole coils could be excited up to 300 A whereas currents of only 65/85 A are sufficient for correction.

Two superconducting 1.8 m long quadrupoles which match to the hybrid dipole magnets have been built and successfully tested in Saclay, France. All 224 quadrupole magnets have been ordered. Half of these magnets are contributed by and built in France.

The cable for all quadrupole magnets has been delivered. The production of the dipole cable is under way. The short samples are being measured at BNL.

A string of 3 hybrid dipole and 2 quadrupole magnets is being assembled and prepared for a system test [Fig. 6].

The Cryogenic System [13]

The liquid helium facility with a capacity of 20.3 kW at 4.4 k consists of 3 cold boxes, 14 screw compressors, oil separator and cooling systems etc... The construction of the 3 liquifier plants is far advanced. Test runs of the compressors are under way and the first plant is almost ready for acceptance runs.

Assuming a safty factor of 1.5 in calculating the total heat leakage two liquifier plants would be sufficient to run the p-ring. The third plant is for redundancy.

The helium distribution system consisting of a 6 km long transfer line in the tunnel, 8 feed boxes and 8 JT valve boxes has been redesigned. In the tunnel the boxes will be distributed in such a way that the 2 phase helium is always flowing up hill in the machine plane which is inclined by 1 %. Tenders for the helium distribution system have been invited and the schedule foresees that the installation will be complete by mid 1989.

Radio Frequency Systems

The e-ring will be equipped with 84 five- and seven-cell rf-cavities (500 MHz) and 6 transmitters with a total cw output power of 7 MW. This equippment which is being removed from PETRA is sufficient to run the e-ring up to 26 GeV in stage I. With the remaining rf in PETRA (16 cavities, 2 transmitters) electrons or positrons can be preaccelerated up to 14 GeV.

A development program for 500 MHz superconducting cavities with 2 x 4 cell structures in one cryostat is under way [14]. The first of 2 prototype cryostats has been delivered and the first 4 cell structure is being installed and prepared for testing.

It is believed that the technology of superconducting cavities is far enough advanced to be put into action and that in a first step the e-ring energy should be upgraded to 30 GeV by installing 8 cavity units in the straight section West. The go ahead for this program is expected after extensive beam tests on the prototype cavities have been carried out in PETRA.

The proton rf-systems for DESY III, PETRA II and HERA have been designed in cooperation with CERN, Chalk River and Rutherford Laboratory. In HERA, 2 rf-systems at 52 MHz (2 cavities) and 208 MHz (4 cavities) will be used for proton acceleration and bunching. The proton rf-system for PETRA II (2 cavities, 52 MHz) is being contributed by Canada and built in Chalk River.

The 208 MHz cavities including transmitters have been ordered. A test transmitter from CERN is working at full power (60 kW).

In DESY III a PS type cavity from CERN will be used for acceleration to 7.5 GeV.

Injection

With the exception of DORIS all accelerators on the DESY site are involved in the HERA injection scheme [Fig. 7]. The e-injector chain consists of the $e^{\pm}$-linacs, PIA (positron accumulator), DESY II, PETRA II and various transfer channels. DESY II, the new 7 GeV $e^{\pm}$-synchrotron, which has recently been put into operation is described in a special paper [15]. PETRA II, the preaccelerator for both HERA rings is currently being prepared for acceleration of electrons or positrons to 14 GeV and of protons to 40 GeV in a second step.

When accelerating protons in PETRA II the beam will bypass the electron cavity section through an extra FODO channel. The bypass will be built in October 1987.

The p-injector chain starts with a H^-- source followed by an accelerating rf-quadrupole, a 50 GeV linac and DESY III, a new 7.5 GeV synchrotron. The source and the rf-quadrupole, which has been built at the University of Frankfurt a.M., are working. The linac is under construction. Work on DESY III which is described in a special paper [16] has been started. The magnets of DESY I will be reused in DESY III.

Time Schedule

The p- and e-injection channels will be tested using positrons and electrons in April and in July 1987. The service installations in the first tunnel quadrant are far enough advanced that the installation of e-ring magnets can be started. By April 1988 the e-ring will be closed and a beam will be stored. The completion of the proton ring is foreseen for the second half of 1989 and colliding e-p beams may be available in 1990.

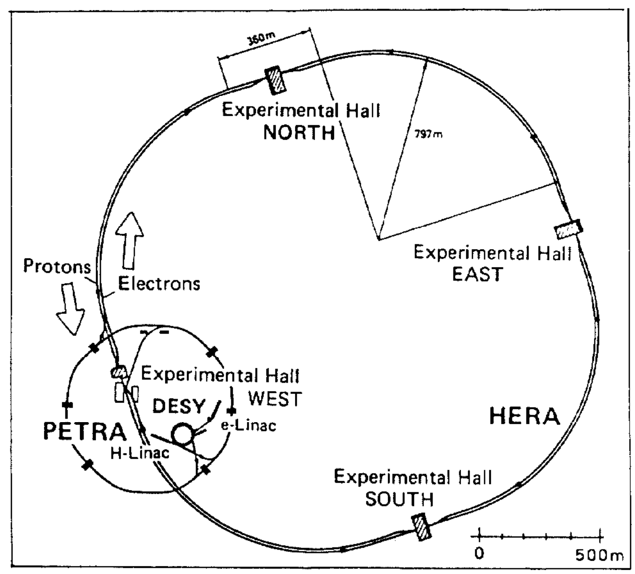


Fig. 1 Layout of the HERA storage rings

Table 1 MAIN PARAMETERS of the HERA STORAGE RINGS

	electron/ positron ring		proton ring	
Energy	30		820	GeV
Circumference		6336		m
Length of each (of 4) Straight sections		360		m
Number of IP's		3(4)		
Magnetic bending field	0.185		4.53	T
Injection energy	14		40	GeV
rf-frequency	500		52/208	MHz
Max. circumfer. voltage	165		0.3/2.4	MV
No. of bunches	210		210	
Aver. beam current	58		130	mA
Beam size at IP (sigma x/z)	.29/.077		.293/.066	mm
Crossing angle		zero		
Luminosity per IP		1.5 E31		1/cm*cm*sec
Freespace for experiment		11		m

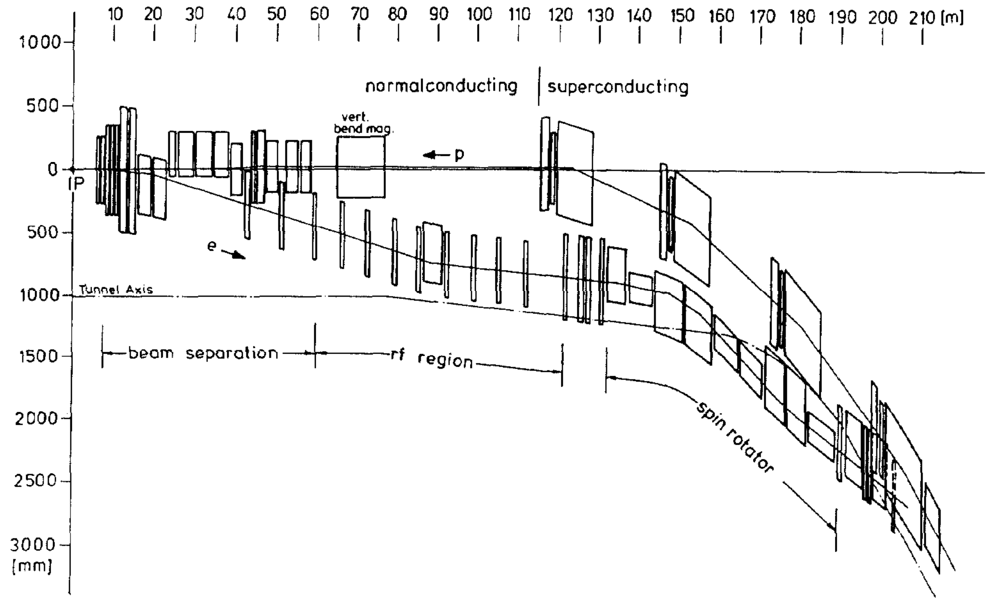
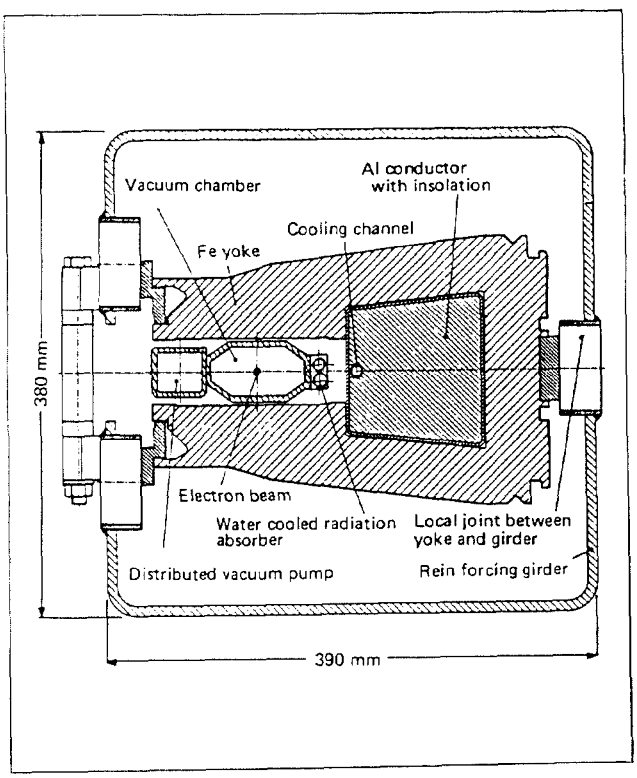


Fig. 2 HERA straight section with electron proton head-on collision geometry



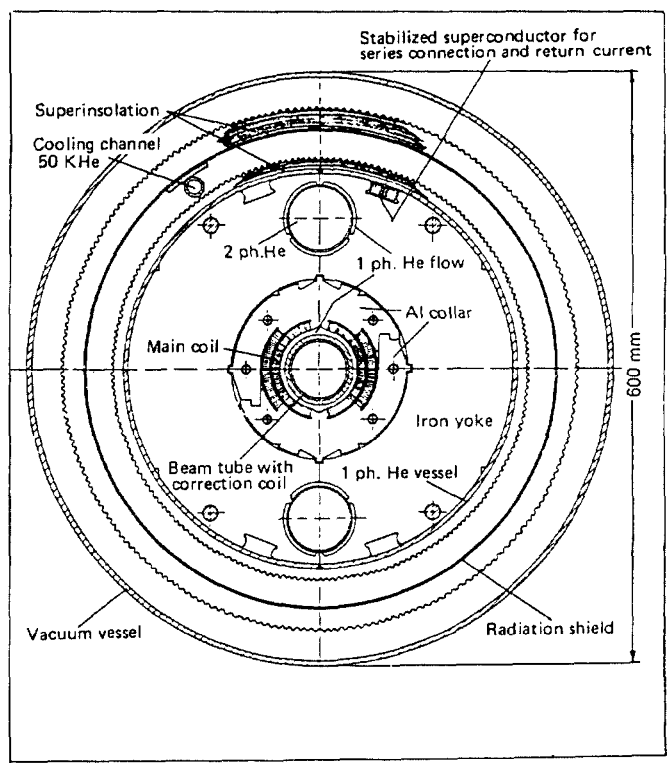


Fig. 3 HERA electron ring bending magnet

Fig. 4 Cross section of superconducting HERA proton ring bending magnet

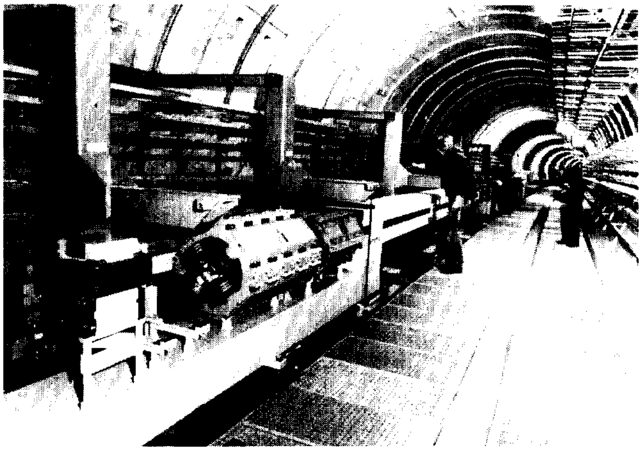


Fig. 5 Electron ring magnet modules in the HERA ring tunnel

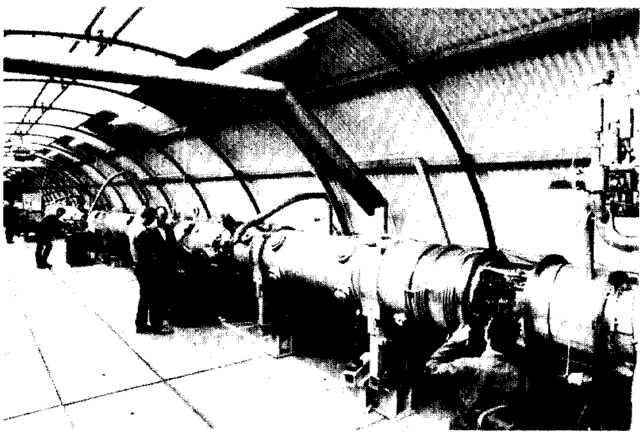


Fig. 6 A string of 3 superconducting dipole and 2 quadrupole magnets is being prepared for a system test

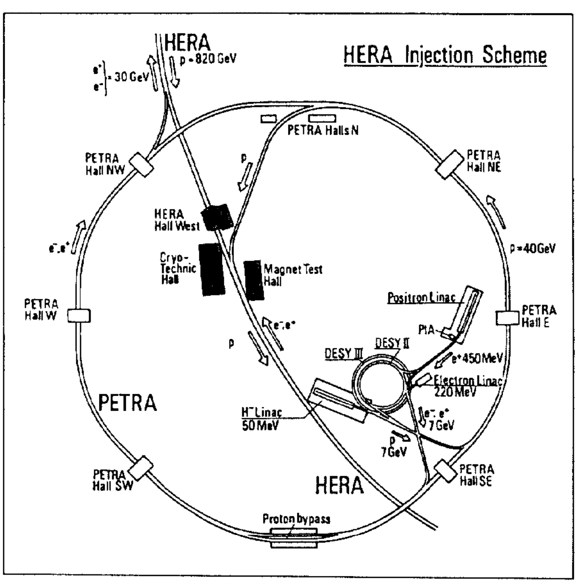


Fig. 7 HERA injection scheme

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