THE HERA STRAIGHT SECTIONS

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Abstract

An updated description of the HERA straight sections for head-on collisions is presented. The electrons and protons are separated in combined function and bending magnets in the electron low beta insert.

Synchrotron radiation emitted in the separator will be collimated and absorbed in such a way that photon backgrounds in the HERA detectors become tolerable.

The magnets in the proton low beta insert will be normalconducting.

The spin mini rotator scheme will be used to achieve longitudinal electron beam polarization. The optical flexibility of both HERA rings allows us to have a spin-transparent electron optics and a special proton injection optics which after energy ramping will be tuned to the low beta luminosity optics.

The maximum luminosity as limited by the beam-beam forces is expected to be

$$2.5 \times 10^{31} cm^{-2} sec^{-1}.$$

In HERA stage 1 a special straight section without interaction will be installed in the West area to improve the conditions for proton injection and the beam abort system.

Introduction

Electrons and protons will collide head-on in the interaction points of HERA. The previous scheme with crossing angle has been dropped in order to avoid satellite resonances which are generated by the interaction of crossing beams.[1,2,3,4] Computer simulations have shown that those resonances can lead to a severe increase of the proton beam emittance.[5]

The layout of the HERA straight sections is based on the following design criteria:

* The longitudinal polarisation of the electron beam is achieved by using the spin mini rotator scheme in a straight section lattice which is symmetric about the interaction point.[6,7]
* The head on collision scheme for HERA requires that the electron (e)-beam is deflected horizontally away from the proton (p)-beam. This horizontal deflection of the e-beam has to be integrated into the spin mini rotator system. The e-p separation should be strong and close to the interaction point (IP) in order to place the p-low beta insert close to IP and to gain sufficient space for the e-ring rf-cavities.
* Around the IP's sufficient space has to be provided for particle detector equipment. The detectors have to be carefully protected against synchrotron radiation photons which are emitted in the e-p separators. In order to keep the radiated power and critical photon energy below tolerable limits the separator magnets should be long and weak.
* The p-ring magnets in the low beta insert will be normal conducting. All superconducting p-ring magnets can then be of the standard types with an aperture radius of 28 mm.

The Interaction Region

Fig. 1 shows a top view of the interaction region and Fig. 2 of the entire straight section which by definition extends from the IP to the beginning of the normal arc structure of both rings. The distance between the IP and the yoke of the first machine magnet is 5.8 m. The detector equipment may extend up to 5.5 m in the vicinity of this magnet.

A triplet focussing system has been chosen for the low beta insert in the e-ring. The insert has 3 groups of quadrupoles of which the first one is vertically focussing. With 2 exceptions all quadrupoles in the triplet are displaced horizontally off the e-orbit in such a way that they work as combined function magnets and produce nearly half of the e-beam deflection which is needed for e-p separation. With the required quadrupole strengths the displacements range from 5 to 12 mm. The e-p separation is completed by 2 dipole magnets, and the total separation angle is 10 mrad. The bending power in the separator region is equally distributed between the combined function and the dipole magnets. Thus the required large bending radius of 1360 m is achieved.

Synchrotron Radiation in the Interaction Region

At the design e-beam energy of 35 GeV and the design current of 58 mA the radiated synchrotron radiation power from each e-p separator is 9 kW. The critical photon energy is 70 KeV. The number of radiated photons with an energy in excess of 20 KeV is $7.8 \times 10^{17} sec^{-1}$. The sensitive detector elements like particle tracking chambers and scintillators which are installed close to the beam line have to be protected against scattered synchrotron radiation. Chamber life-time as well as event pattern recognition considerations lead to the conclusion that a flux of some 10^8 photons per sec in a HERA detector can be tolerated.[8]

Fig. 3 shows the longitudinal synchrotron radiation profile in the interaction region. With 3 upstream collimators (C1, C2, C3) the fan of produced photons is collimated to a size which allows the photons to pass through the beam pipe in the detector and the downstream e-ring magnets without hitting the vacuum chamber walls. The apertures of the e-insertion magnets have been chosen such that this scheme can be realized. The synchrotron radiation which passes through the interaction region and the radiation emitted in the downstream e-p separator will hit absorbers (A1 and A2) which are 24 m away from the IP. The backscattering of photons from the absorbers and the edgescattering from the collimators are strong sources of secondary radiation. The detectors are protected against this radiation by collimators C4 and C5 in the beam pipe.

All collimators and absorbers will consist of tungsten which is coated with 0.5 mm thick layers of silver and copper. The coating reduces the albedo of synchrotron radiation to a few % of that of pure tungsten[9].

This radiation protection scheme has been computer simulated with the result that the photon flux in the detector will not exceed some 10^8 photons per sec.[8]

Electron Optics and Lattice in the Straight Section

The e-beam leaving the separator passes through a FODO-channel where rf-cavities will be installed, and then through the chain of spin rotator magnets. In the rf section, small $\beta_{x,z}$ and dispersion values are desirable. Horizontal dispersion (D_x) is generated in the separator and is unavoidable. But due to the triplet focussing with moderate β_x-values, D_x can be kept below 0.2 m in the 84 cavities which will be installed in 3 HERA straight sections.

The e-p separator bending fields and a translating dipole magnet in the rf channel have been integrated into the spin rotator scheme[7]. The latter magnet is necessary to achieve spin matching for horizontal synchrotron oscillations. A detailed description of the mini rotator scheme and a complete reference list is given in reference 7.

Up to 33 individually powered quadrupole circuits will be available as to satisfy the various optics and spin matching conditions. The resulting e-luminosity optics with $\beta_x^* = 2$ m, $\beta_z^* = 0.7$ m and $D_{x,z}^* = D'_{x,z}{}^* = 0$ is shown in Fig. 4. In a machine without imperfections the degree of polarisation would be as high as 84 %.[7]

Proton Optics and Lattice in the Straight Section

Normal conducting magnets will be used in the p-low beta insert as well as for bending the p-beam vertically off the e-ring plane. About 115 m away from the IP the p-beam enters the superconducting magnet lattice which has the standard aperture radius of 28 mm. After passing through 4 modified p-half cells the p-beam is bent vertically into the p-ring plane which is 81 cm above of the e-ring.

About 24 m away from the IP the e-p separation is large enough to install septum-like quadrupoles as part of the p-low beta focussing doublet. A group of 3 half quadrupoles (4 m long, 50 mm bore radius) plus a conventional quadrupole (3 m long, 35 mm bore radius) and a second group of 3 further conventional quadrupoles serve as the focussing elements in the doublet.

A dipole septum magnet in front of the doublet and a dipole magnet in its center serve to correct for the orbit kicks which the p-beam suffers in the half quadrupoles and in the e-p separator. The nearly local correction of these kicks with the septum magnet is needed when switching from the electron-proton to the positron-proton collision mode with reversed magnet polarities in the e-ring.

A special p-optics with maximum β-values below 350 m will be used at injection where the largest machine acceptance is needed. Using this optics, the injection acceptance will not be restricted by the magnet apertures chosen in the low beta insert[10]. After energy ramping the straight section will be tuned to the luminosity optics. The optical flexibility for the tuning is supported by superferric quadrupoles which will be installed next to the main quadrupoles in the modified superconducting half-cells. The luminosity optics with $\beta_x^* = 10$ m, $\beta_z^* = 1$ m and $D_{x,z}^* = D'_{x,z}^* = 0$ is shown in Fig. 5.

The Luminosity

The maximum achievable e-p luminosity is limited by the beam-beam forces. With the chosen optical parameters and assuming

$E_p = 820$ GeV	$E_e = 30$ GeV
$N_p = 1.0 \times 10^{11}$/bunch	$N_e = 3.6 \times 10^{10}$/bunch
$\varepsilon_{x,p} = 0.5 \times 10^{-8}$ m	$\varepsilon_{x,e} = 1.6 \times 10^{-8}$ m
$\varepsilon_{z,p} = \varepsilon_{x,p}$.	$\varepsilon_{z,e} = 0.1\ \varepsilon_{x,e}$
	(90° phase advance/cell)

the luminosity will be

$$L = 2.5 \times 10^{31} \mathrm{cm}^{-2}\mathrm{sec}^{-1}$$

and the beam-beam tune shifts are close to the assumed tolerable limits ($\Delta Qe < 0.03$, $\Delta Qp < 0.003$)

$\Delta Qx,p = 0.0026$	$\Delta Qx,e = .023$
$\Delta Qz,p = 0.0016$	$\Delta Qz,e = ,026$

It has been proposed that the e-p luminosity be measured using the bremsstrahlung process.[11] Bremsstrahlung photons from the e-p interaction are emitted in the e-direction, pass through the p-insertion magnets and separate from the p-beam after the vertical bending magnet. The aperture of this magnet will be large enough to ensure that the beam of bremsstrahlung photons is not obstructed.

The Straight Section West

A special straight section without interaction region, spin rotators and vertical p-bending will be installed in the HERA West area. The lattice of the straight section West (Fig. 6) is opimized according to the needs of p-injection and the beam abort systems. The considerably improved p-injection scheme is expected to be especially advantageous in the first years of HERA operation. Presumably only 2 detectors have to be supplied with luminosity during this phase. The later installation of an interaction region is possible. The main features of the straight section West are:

* In the e-ring additional space for rf-cavities is gained in a long FODO channel where the dispersion is zero.
* A combination of weak and strong bending magnets provide optimum conditions for operating a laser polarimeter. Only synchrotronradiation from the weak bending magnet will hit the polarimeter.[12]
* In the p-ring normal conducting quadrupoles will be installed in a FODO channel where the beam dump and the dump kickers can be arranged in such a way that minimum kicker-strength is needed.
* The layout of the superconducting lattice and the p-optics enables us to use only one kicker for p-injection. The kicker can be placed 90° in phase downstream from the horizontal injection septum. No DC bump is necessary to support the septum. Thus the injection acceptance will not be restricted. The clearance between the injected beam and the superconducting elements will be increased.

Acknowledgements

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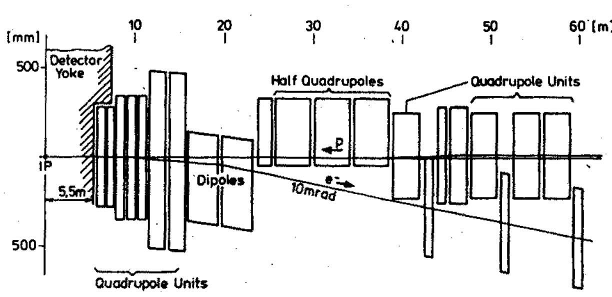

Fig. 1. HERA interaction region with electron proton head-on collision geometry

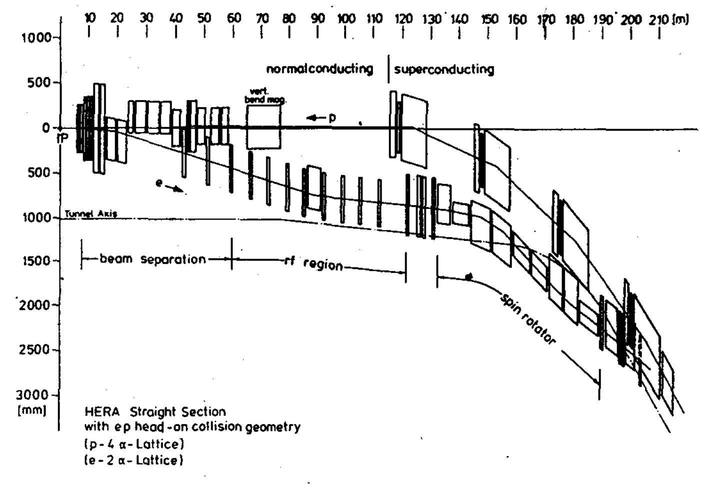

Fig. 2. HERA straight section with spin mini rotators in the electron ring

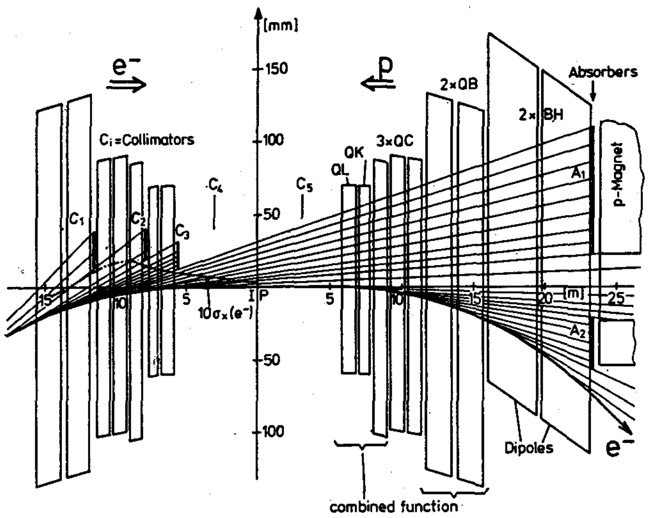

Fig. 3. Longitudinal synchrotron radiation profile in the interaction region

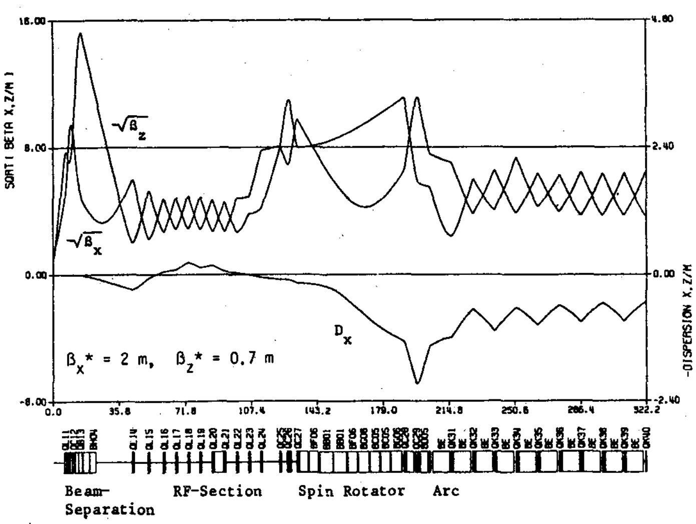

Fig. 4 HERA electron luminosity optics

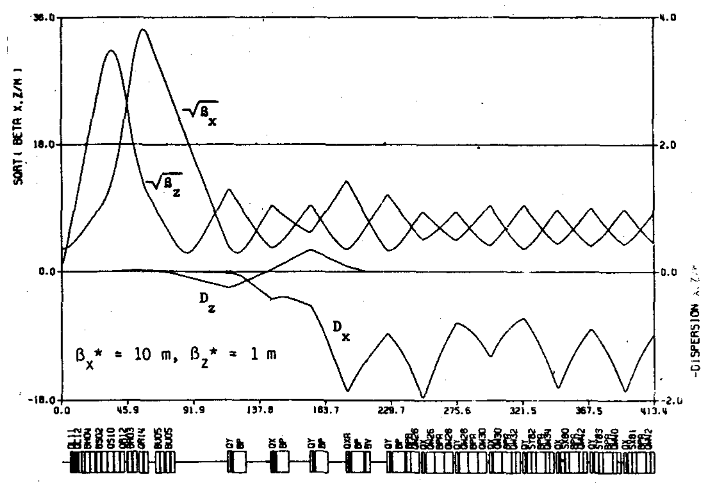

Fig. 5. HERA proton luminosity optics

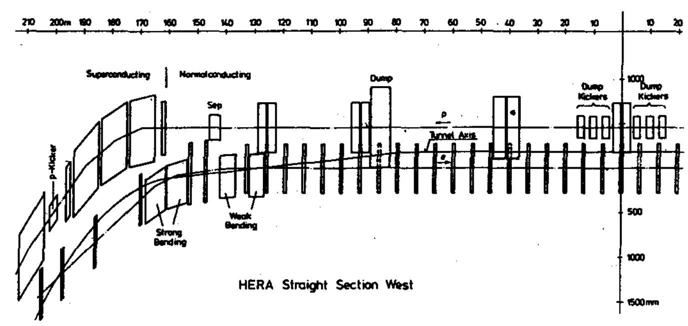

Fig. 6. HERA straight section West

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