DESIGN OF A 3GEV ELECTRON POSITRON DOUBLE STORAGE RING

The DESY Storage Ring Group†)

presented by

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A 3GeV electron positron double storage ring has been designed at DESY and is being proposed for construction as an extension of the DESY facilities. Starting from the earlier DESY proposals[1] and using the fundamental work done at Frascati[2], Cambridge[3], Stanford[4] and other laboratories, the design is aimed at high luminosity and incorporates the low-β insertion as proposed by the CEA group[5,6].

†) The work reported here has been done by the following group:
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The two rings are mounted one above the other with two vertical beam crossings in the symmetry points of two straight insertions which have a length of 60m each. This double ring design was chosen in view of the following advantages as compared to a single ring structure:

1) Electron-electron interactions can also be studied.

2) Long range forces between the two beams are eliminated.

3) Each beam can be measured and controlled independently. This will greatly aid the study of storage ring behaviour and provides more differentiated possibilities fur tuning it up to optimum performance. It allows, for example, to choose slightly different Q-values in both rings and thus to eliminate all coherent beam-to-beam instabilities in a simple way[7]. Also, the rf phases of the two beams can be adjusted independently, which provides a simple means for background measurements at otherwise unchanged beam conditions.

4) Electrodes for beam separation, distributed about the ring, are eliminated.

5) The magnet gap height is reduced such that C-type magnet yokes become economically feasible. As pointed out by Voss of the CEA[8] this leads to a great simplication of the ultra high vacuum pumping system, since the synchrotron radiation can now escape the magnetic field into an outside extension of the vacuum chamber and can be absorbed in a field free region at the end of this extended chamber. Thus, the gas desorption by secondary electrons will be reduced by an expected order of magnitude, such that cryopumps are not necessary and pumping of the ring structure can be done with ion sputter pumps only.

6) With separate rf power sources for each ring, the transmitters can be decoupled from the reflected power due to beam mismatch by a simple magic tee arrangement, thus saving expensive rf circulators.

The site layout of the double storage ring is shown in Fig. 1. The magnet lattice is of the separate function type. The half rings are designed as compact as possible; they each consist of 6 mechanically identical magnet periods with only one extended insertion for injection. The electron and positron beams, respectively, coming from the new 400MeV linac, are accelerated in the DESY synchrotron and transferred into the storage ring at opposite sides. A direct injection from the new linac, mainly intended for test operation, is also possible.

Fig. 2 shows the cross section of the double C-shaped bending magnet with its extended vacuum chamber, and Fig. 3 shows the double quadrupole. For both types of magnets, the manufacturing procedure will guarantee a precise relation in the relative position of the two apertures, such that both rings will be aligned by a single alignment procedure. Rounded pole ends in conjunction with magnetic end guards will be used in all magnets to produce a field map which is highly independent of excitation and has a very linear transverse distribution of the integrated field. The beam separation is 60cm.

Fig. 4 gives the top view and Fig. 5 the side view of a magnet period. The two closely spaced bending magnets are surrounded at each side by half a D-F-D quadrupole triplet. At the downstream end of each magnet, the water cooled synchrotron radiation absorbers will be introduced through a flange in close proximity of an ion sputter pump. The space between quadrupoles will be used for vacuum components and beam monitoring and correcting devices.

In the middle of the long straight insertions, a free length of 5m is provided for experiments around the interaction point. By means of two large aperture quadrupole doublets (Fig. 6), the beam is focused down to a very narrow beam waist at the interaction point. The values of the amplitude functions at this point are 2.5cm vertically and 10cm horizontally. Since in the high energy region the luminosity as limited by rf power and vertical space charge is inversely proportional to the vertical amplitude function at interaction point, and since, in the magnet ring structure, the amplitude function is of the order of 10m, a factor of the order of 400 in luminosity is gained by the beam waist. This, however, requires that the bunch length is not longer than about twice the amplitude function, which is one reason for choosing an rf frequency of 500Mc resulting in a bunch length of about 5cm.

At interaction point, the two beams are made to intersect at a vertical crossing angle of the order of a few mrad, just enough to separate the cores of their vertical density distribution. In order to get a sufficient lifetime against wall losses, the "tails" of this distribution must also be separated before the beams can enter the separate apertures of two vertical septum magnets. This is done by an electrostatic separator of about 5m length which is installed in the drift space following the large aperture quadrupoles. At a plate distance of 8cm, it requires a voltage of 320KV at 3GeV.

The vertical displacement of 30cm for each beam is made with two vertical bending magnets of opposite polarity. This scheme was chosen for economy; it is not nondispersive and, therefore, introduces a small vertical disperion which continues with oscillating polarity around the whole ring. For reasons of symmetry, however, its value at the interaction points is zero. The most important consequence of this vertical disperion is, that the vertical beam size is now also determined by quantum fluctuation and not by gas scattering alone. Fortunately, this will not cause a loss in luminosity if, at high energy operation, only a fraction $\frac{1}{n}$ of the bunches is filled with particles. By installing a chopper in the linac injector, this can be achieved.

The rf cavities will be placed in the quadrupole matching sections at the ends of the long insertions (Fig. 7). A total of 6 triple cavity units will be installed in each ring, being grouped in pairs which each are fed by a 250/500KW klystron. Fig. 8 shows the waveguide feeding system. In a magic tee, the power is divided into two arms which differ in length such that the two waves reflected from the cavities will be out of phase by 180° and thus will flow into an absorber.

The rings are designed for a vertical acceptance of 2 mrad·cm and a horizontal acceptance of 8mrad·cm. The corresponding beam envelopes for a full ring quadrant are shown in Fig. 9, which also give the vertical and horizontal dispersion for a momentum deviation of 0.5 %. The horizontal dispersion is made to identically vanish in the long straight insertions as well as in the insertions for injection. This results in a very small momentum compaction factor of 0.025 which is valueable for obtaining small beam dimensions as well as a long beam life against quantum fluctuation. - The numbers of betatron oscillations per turn are 8.1 horizontally and 6.1 vertically; they can be changed in an appreciable range without severely affecting the amplitude functions.

By virtue of the two pronounced peaks of the horizontal dispersion in two corresponding quadrupoles, the damping of the horizontal betatron oscillations does strongly depend on beam position. This will be used to adjust the beam width as determined by quantum fluctuation by adjusting the frequency of the rf system and, correspondingly, the horizontal position of the closed orbit in order to obtain the optimum beam cross section required for maximum luminosity. For example, a frequency shift of 30KHz, causing a maximum shift of 11mm in beam position, reduces the damping constant to 30% of its value at nominal frequency. A required increase of vertical beam size will be produced by coupling.

The luminosity calculated as a function of energy is shown in Fig. 10. The maximum value at 1.5GeV is about $5 \cdot 10^{33} \text{cm}^{-2} \text{sec}^{-1}$ at a circulating current of about 15A in each beam. Above 1.5GeV, the luminosity is limited by space charge and rf power. Below 1.5GeV, the storage ring operates aperture- and space charge-limited, and at still lower energies the Touschek effect becomes dominant. The dashed curve correponds to a mode of operation in which only one out of 8 bunches is filled with particles.

The cost of the storage ring will be 50 Million DM. A detailed proposal has been prepared and will be issued shortly.

References

1) DESY Storage Ring Proposals (1966, 1967)

2) Frascati (ADONE) Storage Ring Proposal (1963)

3) Cambridge (CEA) Storage Ring Proposal (1965)

4) Stanford (SLAC) Storage Ring Proposals (1964, 1965, 1966)

5) K.W. Robinson and G.A. Voss, Report CEAL-1029(1966)

6) M.S. Livingston, Report CEAL-1028(1966)

7) A.M. Sessler, priv. comm.

8) G.A. Voss, priv. comm.

DISCUSSION (condensed and reworded)

F. Amman (Frascati): I would like to comment on the advantages you quoted for two rings as opposed to one ring. Those for e^-e^- physics and elimination of long range forces I would agree with.

As for point three, rf phases can be adjusted independently with one ring. We intend to do it at Frascati. Our rf cavities are spaced far enough apart that we can shift the crossing in time adequately. In point four, elimination of distributed electrodes, that is correct but in fact you have about 40 m. of separators at 320kv.

Point five says that the extended vacuum chamber is possible with two rings. But it is also true of one ring if you fix the orbit and the crossing angles.

Sands (SLAC): How much does the two ring structure cost?

Steffen: 50 M marks. The old structure with 1 ring was 40M marks.

K.H. Reich (CERN): Which elements determine the 60m spacing of the rings?

Steffen: Deflecting magnets and vacuum components.

Reich: What are the alignment tolerances of the interaction region triplet?

Steffen: We hope to achieve a few hundredths of a mm, using conventional surveying techniques.

C. Pellegrini (Frascati): The effects of the coherent interaction between the beams at points where they cross in time but not in space can be eliminated by providing a Q-shift between the beams.

Sands: Did you throw out electrostatic quadrupoles for Q-shifting?

Steffen: Yes. It is simpler to separate the rings and choose different Q-values.

Morton (SLAC): About the long-range forces between beams: Do the beams not go through the last quadrupole before the interaction region together?

Steffen: In these regions the centers of the Gaussian distributions are separated only by a factor of two.

Morton: If this is the worst point it may not be worthwhile to separate them elsewhere.

Steffen: We have not investigated that point. It is possible to build an expanded vacuum chamber for one ring but economically it is not so feasible.

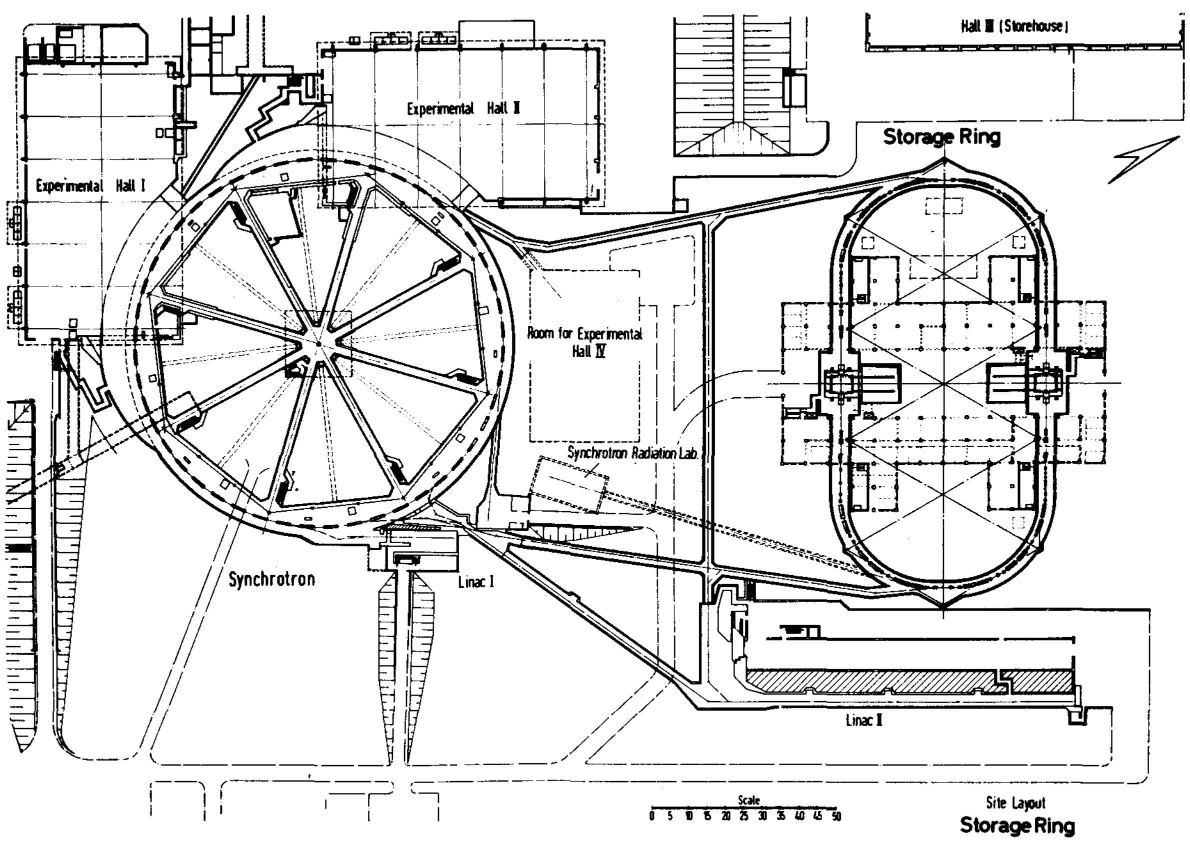
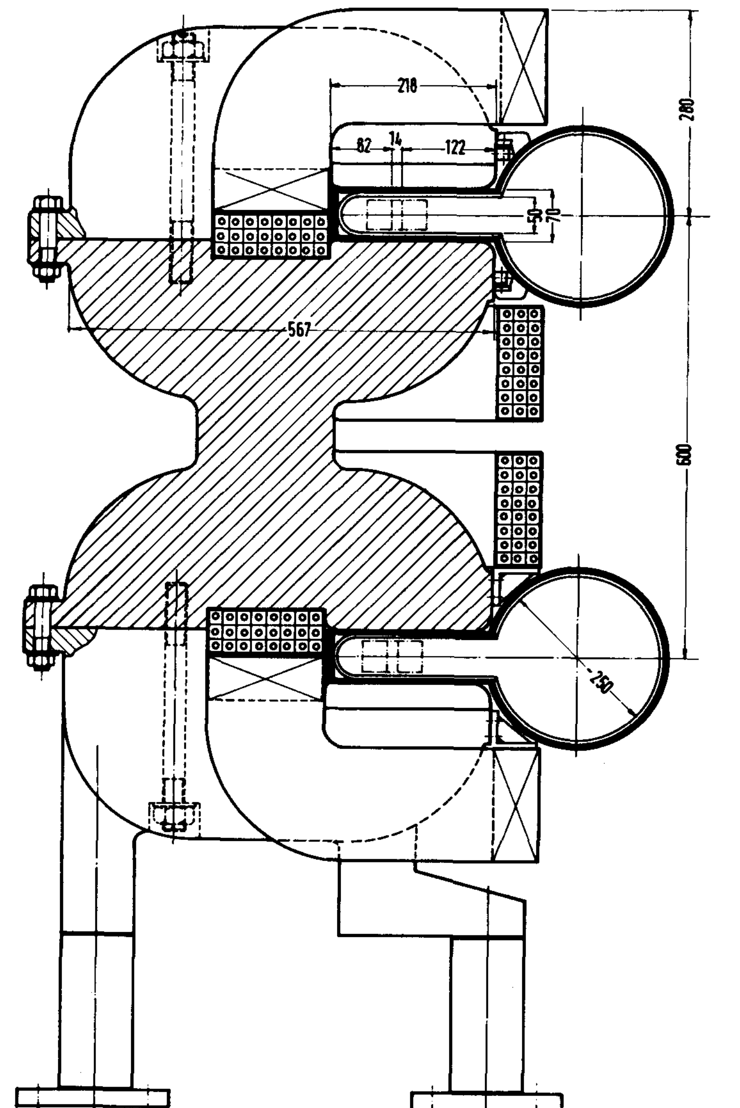


Fig. 1

Site layout of double storage ring



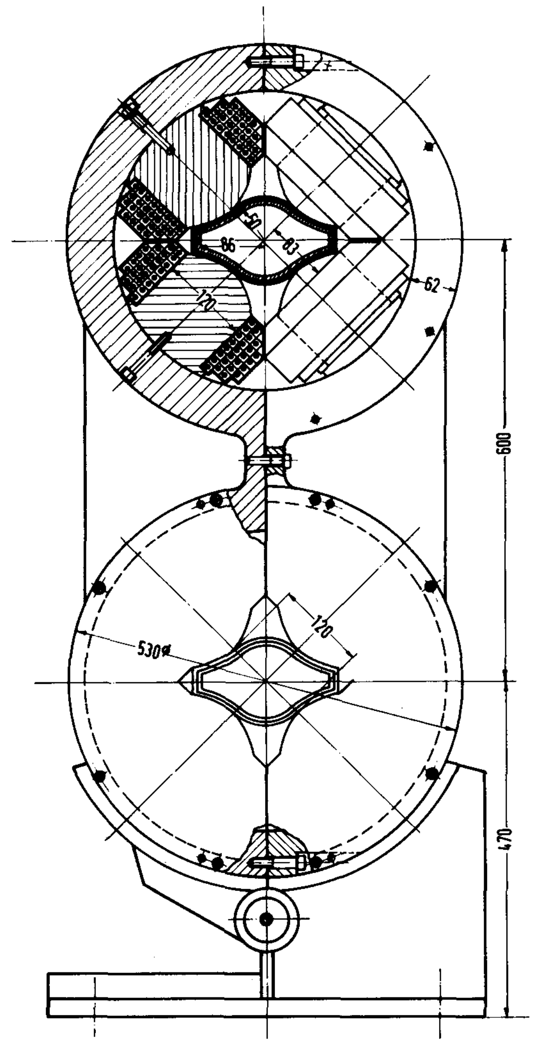
Double Bending Magnet Type MS

Technical Data of Single Magnet (3 GeV) Total Weight ~ 15,5 T

Field strength	8,1kΓ	Average length per turn	7100mm
Current	950A	Cross section of conductor	18x18mm² mit 8∅mm
Voltage	23,5V	Number of water circuits per coil	1
Resistance at 50°C	0,0246Ω	Water flow rate	8l /min
Power consumption	22,2 kW	Pressure drop	5,7at
Magnetic length	3250mm	Weight of copper	840kg
Number of turns per coil	24	Weight of iron	6,85 to

Fig. 2

Double bending magnet



Double Quadrupole Magnet Type QS

Technical Data of Single Magnet (3 GeV) Total Weight 2 T

Field gradient	1kΓ/cm	Average length per turn	1400mm
Current	572A	Cross section of conductor	11x11mm² mit 4∅mm
Voltage	15V	Number of water circuits per coil	1
Resistance at 50°C	0,0265Ω	Water flow rate	3,2l /min
Power consumption	,6 kW	Pressure drop	1,8at
Magnetic length	590mm	Weight of copper	140 kg
Number of turns per coil	25	Weight of iron	820kg

Fig. 3

Double quadrupole magnet

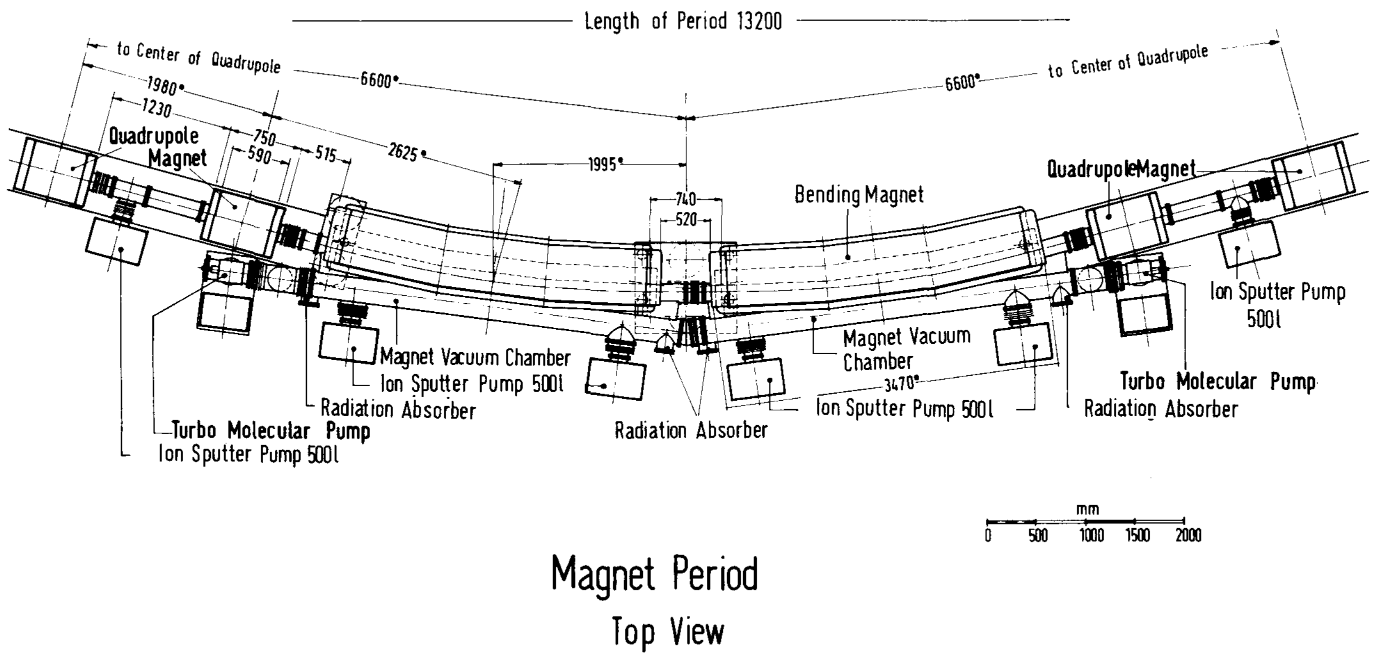


Fig. 4
Top view of magnet period

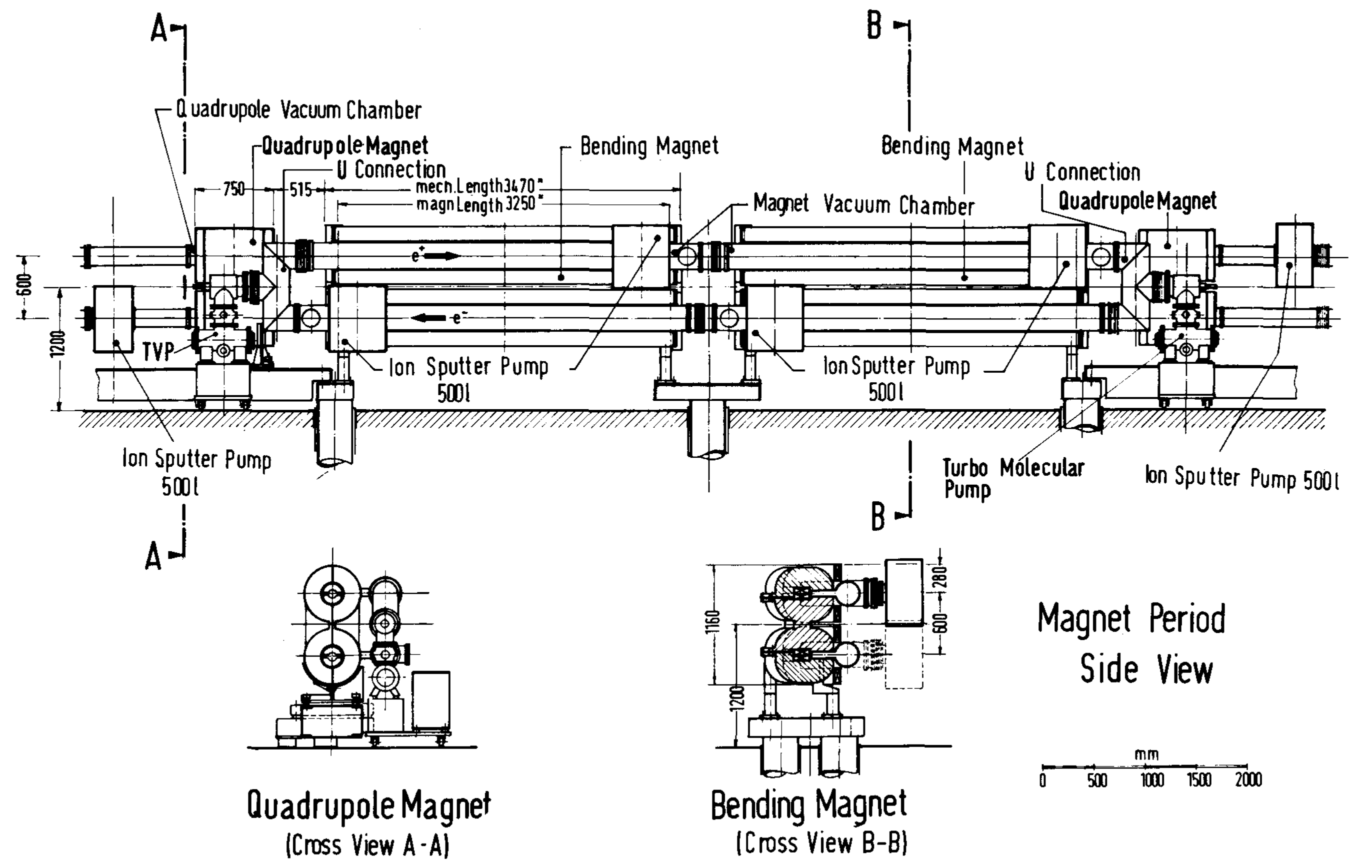
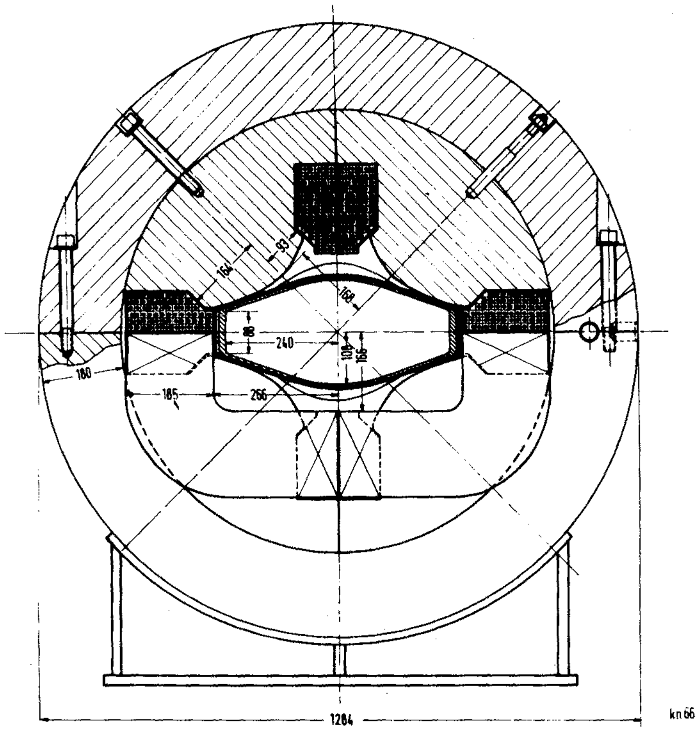


Fig. 5
Side view of magnet period



Quadrupole Magnet Type: QT Total Weight :~11,2to

Technical Data (3 GeV)

Field gradient	0,69 kΓ/cm	Average length per turn	3275 mm
Current	1130 A	Cross section of conductor	13x13 mm² mit 6 ∅ mm
Voltage	145 V	Number of water circuits per coil	6
Resistance at 50°C	0,13 Ω	Water flow rate	58 l/min
Power consumption	162 kW	Pressure drop	3 at
Magnetic length	1100 mm	Weight of copper	1,15 t
Number of turns per coil	69	Weight of iron	10 t

Fig. 6

Fig. 6 Large aperture quadrupole

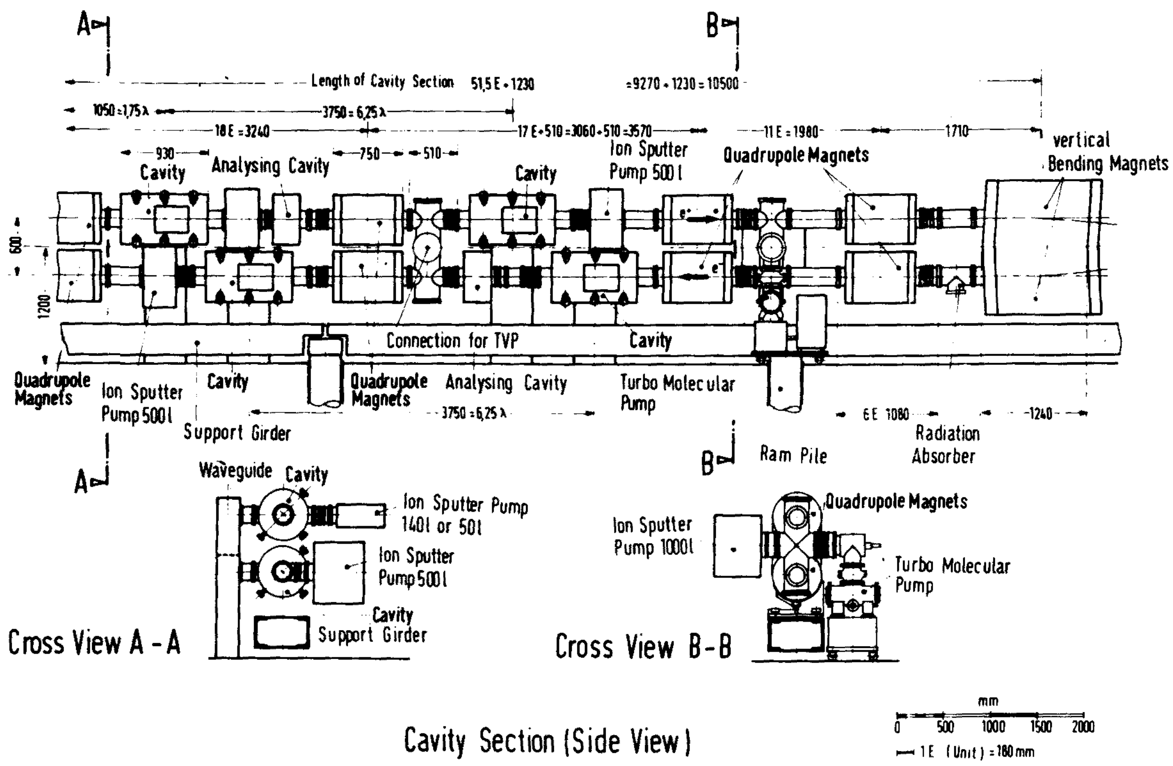
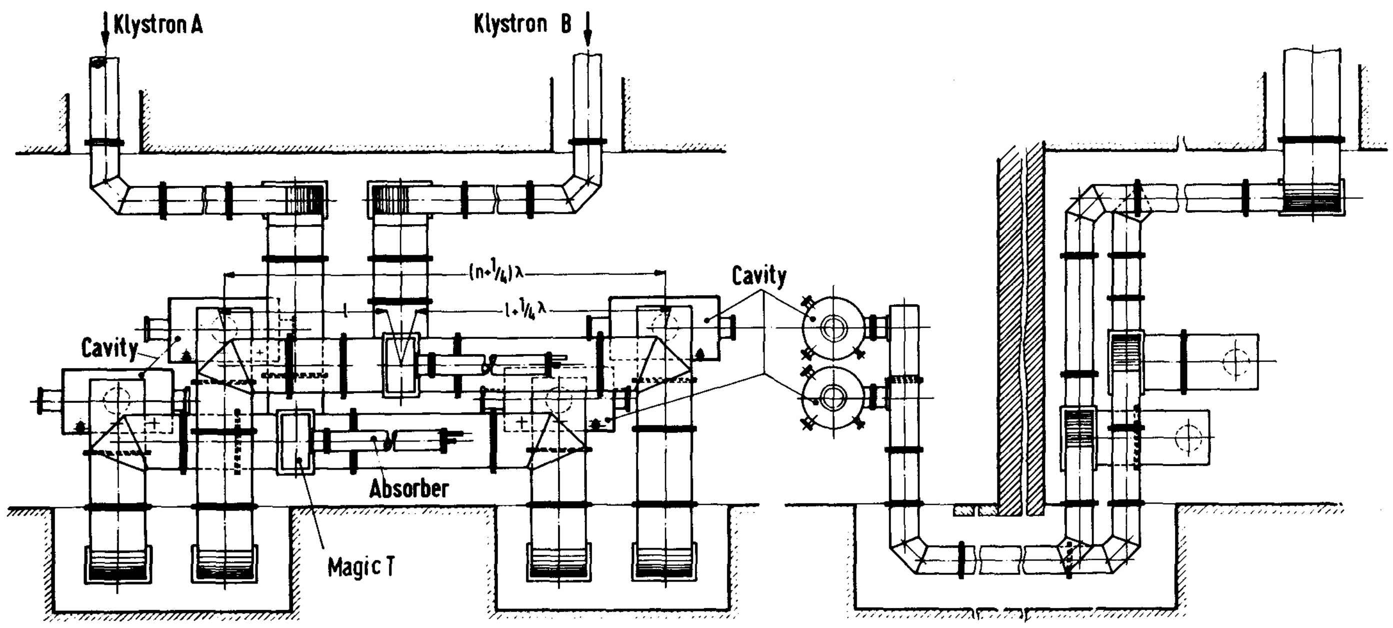


Fig. 7

Fig. 7 Cavity section



RF Layout

Fig. 8

Wavequide feeding system

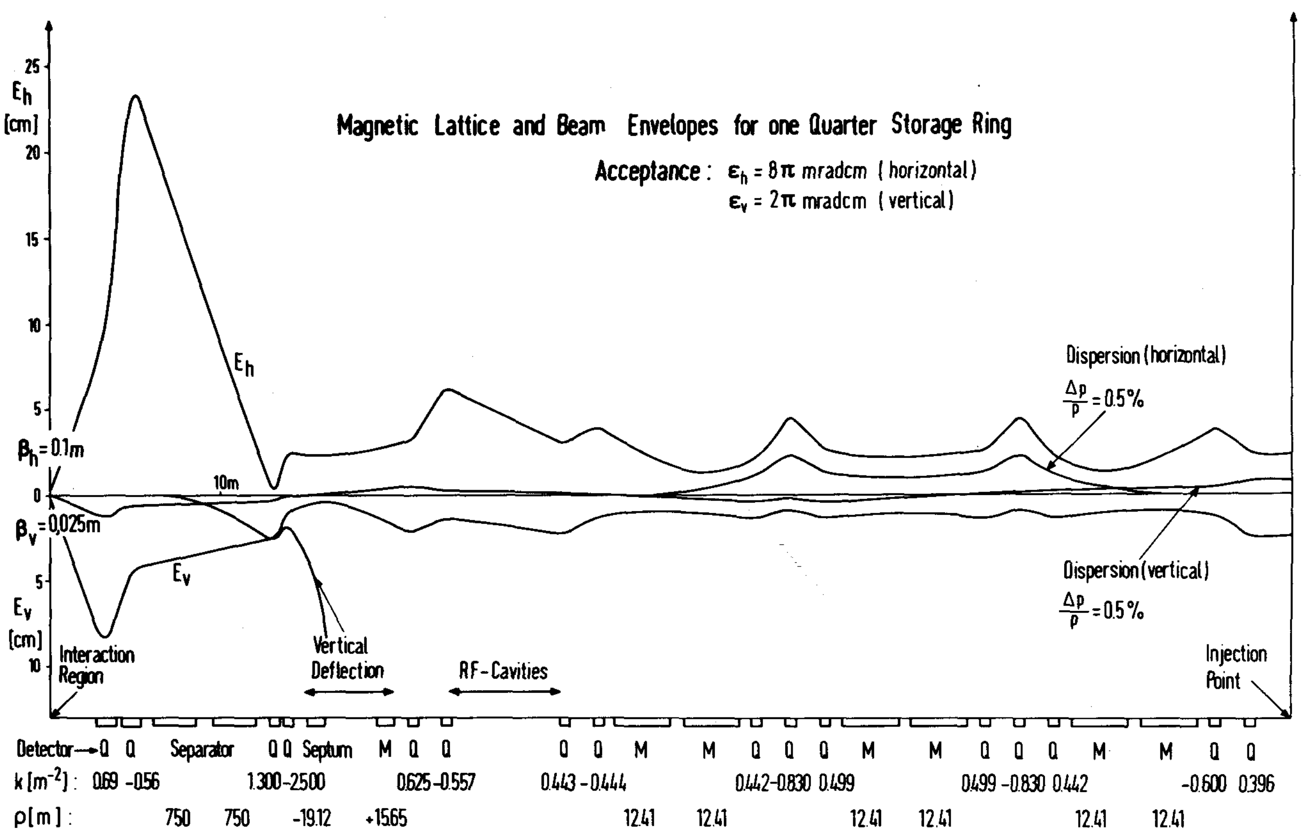


Fig. 9

Magnet lattice, beam envelopes and dispersions for one quarter storage ring (ε_h = 8mrad·cm, ε_v = 2mrad·cm, $\frac{\Delta p}{p_o}$ = 0,5%)

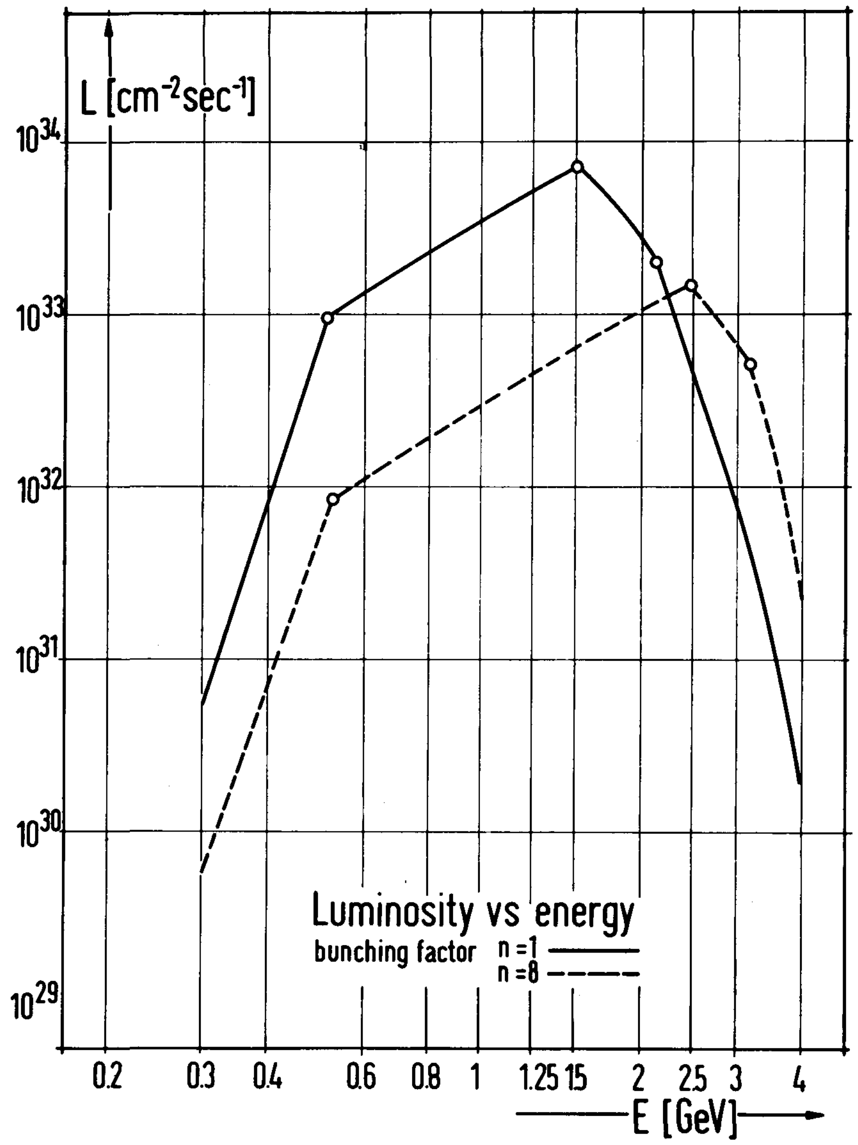


Fig. 10

Fig. 10 Calculated luminosity versus energy