

FINAL PARAMETERS AND STATUS OF DESY DOUBLE STORAGE RING

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Since the fall of 1967, when the proposal of the DESY 3 GeV double storage ring was submitted, the continuous review and further development of the project has lead us to improve many features in detail but has, however, convinced us that the basic concept and ring geometry should be maintained.

The most fundamental question raised by these investigations and especially by the new double storage ring schemes proposed at SLAC and Orsay was that of crossing geometry and luminosity as limited by the incoherent space charge effect. Applying the schemes of

- small angle vertical crossing, or
- large angle horizontal crossing, or
- space charge compensated 4-bunch collision, respectively

to the DESY-rings, we obtained the luminosity curves shown in Fig. 1. The solid curves No. 1 and 2 refer to small angle vertical crossing with two different values β_x of the horizontal amplitude function at interaction point and the same value $\beta_z=10$ cm. The lower curve holds for $\beta_x=10$ cm, where the full ring acceptances $\epsilon_x=8$ mradcm and $\epsilon_z=0,8$ mradcm are available, as needed for injection. After injection, β_x can be reduced to 2,5 cm, which reduces the horizontal acceptance to 2 mradcm. Applying this reduction to the extent compatible with natural beam width, the upper luminosity curve is obtained. The crossing angle is chosen just large enough to vertically separate the beams and varies between 12 mrad and 28 mrad, depending on energy. For high energies, the bunch population number is varied too, assuming that only every 2nd, 8 th or 16 th bucket, respectively, is filled. The dotted curve No 3 is obtained for horizontal crossing with $\beta_x=\beta_z=10$ cm at a fixed crossing angle of 200 mrad, the population number being varied as before at high energies. The curves No 1, 2 and 3 are calculated for an rf frequency of 500 MHz but are insensitive to changing the harmonic number. Curve

No. 4 shows the luminosity for the space charge compensated scheme with an rf frequency of 5 MHz and only two oppositely circulating bunches in each beam ($\beta_x, \beta_z > 30$ cm).

Since the luminosity for all schemes is of the same order, we have decided to stay with the small angle vertical crossing, thus avoiding a substantial increase in construction time and cost of the buildings.

In distinction to our 1967 proposal, we have eliminated the high voltage electrostatic separators, at least for the initial stage of construction, by slightly increasing the crossing angle such that the beams can be separated by inserting a current sheet septum between them. The main vertical beam displacement is then achieved by two vertically bending double magnets as described in the original. The vertical dispersion introduced by these magnets allows to vary the natural beam height by varying the optical matching of the long straight sections. A side view of the crossing geometry with horizontal and vertical beam envelopes is shown in Fig. 2 a, b. Before reaching the septum, the beams pass through two common large aperture quadrupoles, which are shown in Fig. 3. The apertures available for the upper and lower beam in the first and second quadrupole, respectively, are indicated by ellipses. The quadrupole next to the interaction point is horizontally focusing. With $\beta_x = \beta_z = 10$ cm at interaction point, the maximum values of the amplitude function are 90 m and 700 m, respectively. The expected closed orbit deviation generated by a statistical misalignment of 0,1 mm in these 8 quadrupoles is smaller than 4 cm and 20 cm, respectively, and will be controlled by beam steering.

The main ring geometry has not been changed (Fig. 4 a). Each quadrant (Fig. 4 b) consists of 3 mechanically identical magnet periods surrounded by a short straight section for injection and the long straight section holding the interaction region, the vertical beam separation and the radiofrequency system. The two short straights not needed for injection may be used for controlling the damping distribution by displacing the beam in a quadrupole channel. Fig. 5 shows the horizontal and vertical beam envelopes in one quadrant between interaction point (left) and injection point (right). The Q-values are 10,1 and 4,1 for the horizontal and vertical motion, respectively; they can be varied by about ± 1 . The horizontal dispersion is matched to be zero in the long straights while, for minimum natural beam height, the vertical dispersion can be matched to be zero in the ring parts.

Fig. 6 gives the cross section of the bending magnets, which are curved and made of solid low carbon steel. The tracking of solid magnets has been tested at DESY and was found satisfactory. All magnets have been changed to allow a maximum beam energy of 4,5 GeV; correspondingly, the vertical displacement between beams was raised to 80 cm. The stainless steel vacuum chamber (Fig. 7) has outside ribs for reinforcement and can be baked in place. Ion getter pumps are located between the upper and lower chamber.

The double quadrupoles (Fig 8.) will be manufactured with high intrinsic and relative accuracy using precision assembly jigs. Correction coils around and between the poles allow to superimpose corrected horizontal and vertical dipole fields for beam steering. The aperture has been increased to hold a circular vacuum chamber of 14,4 cm inner diameter which—with the exception of bending magnets and interaction regions—continues as a smooth pipe around the ring.

A magnet period is shown in Fig. 9. The absorbers for synchrotron radiation are located in boxes extending the vacuum chambers beyond the ends of the magnets; they will probably be large, water cooled copper cylinders with a V-groove.

The 500 MHz radiofrequency system has 3 klystron transmitters of 250 kW cw for each beam. Each transmitter feeds 4 cylindrical single cavities through a waveguide system incorporating an isolator and magic tees for decoupling of cavities.

An axial view of the cavity is given in Fig. 10, showing the input loop coupler, a tuning plunger and a measuring loop. The Q-value is 40 000 and the shunt impedance 3 M Ω . In beam loaded operation, the cavity is kept tuned on resonance by controlling the plunger. Since the available frequency shift is limited to about 2 MHz, the synchronous phase angle must be small at low energies and, in addition, the total shunt impedance must be reduced by detuning part of the cavities.

The site layout is shown in Fig. 11. Injection is done at about 1,5 GeV from the synchrotron or, mainly for beam tests, directly from the new 400 MeV electron-positron linac. Typical injection times from the synchrotron are 2,5 sec/Ampere for electrons and 2,5 min/Ampere for positrons.

The floor of the high bay connecting the two interaction points is 1,7 meters below beam level. A hole with an area of 8 \times 8 m² and a depth of 4,5 m below beam level is available at one side for varying experimental setups while, at the other side, a much larger hole of same depth is planned for a large retractable magnetic detector. Figure 12 shows an artist's view of the buildings and fig. 13 the beam paths.

Construction funds for the project are available starting this year. The orders for rf transmitters and main ring magnets will be placed within the near future, building construction will start next spring, and the storage ring is expected to be completed in 1973.

Parameters of DESY Double Storage Ring

1. Magnet lattice

Number of magnet periods	2 · 12	
Length of magnet period	13,2	m
Mean radius (without long straights)	26,74	m
Radius of curvature in magnets	12,19	m
Deflecting field at 3 GeV	8,1	Kg
Field gradient in quadrupoles	at $Q_x=10,1$ and $Q_z=4,1$ between 0,4 Kg/cm and 0, 86 Kg/cm	
Amplitude function in bending magnets		
Maximum	11,5	m
horizontal		
Minimum	1,4	m
Maximum	13,5	m
vertical		
Minimum	11,3	m
Maximum amplitude function in the ring		
horizontal	87,5	m
vertical	706	m
Amplitude function at interaction point		
horizontal	0,1	m
vertical	0,1	m
Dispersion in bending magnets		
Maximum	2,2	m
horizontal		
Minimum	0	m
Maximum	0	m
vertical		
Minimum	0	m
Momentum compaction factor	$1,8 \cdot 10^{-2}$	
Crossing angle $\delta=2\Phi$ vertical	between 12 and 28	mrad
Number of long straight sections	2	
Length of long straight section	60	m
Length of principal orbit	288	m
Mean radius including long straights R	42,84	m
Frequency of revolution f_0	1,0410	MHz
Iron weight:		
Bending magnets	550	t
Quadrupoles	240	t
Copper weight:		
Bending magnets	40	t
Quadrupoles	28	t
Magnet Power at 3 GeV	5,6	MWatt

2. RF system

Harmonic number	480	
Frequency	499,67	MHz
Number of klystrons	2·3	
Number of cavities	2·12	
Maximum rf power	2·0,75	MWatt cw

Peak rf voltage per ring at 3 GeV and 16° synchronous phase angle	3,5	MV
Rf beam power at 3 GeV and 16° synchronous phase angle	2 · 0,55	MWatt cw

3. Vacuum system

Ion getter pumps:		
Number of 120 l pump units	96	
Number of 240 l pumps	96	
Number of 450 l pumps	64	
Number of 1000 l pumps	12	
Total pumping speed for N ₂ at 5 · 10 ⁻⁹ Torr	5,6 · 10 ⁴	lsec ⁻¹
Number of ion sputter pumps (open)	48	
Number of cryopumps in interaction regions	4	
Turbomolecular pumps		
Number of 200 l—300 l pumps	48	
Average partial pressures in vacuum system		
Without beam N ₂ , CO	1.10 ⁻⁹	Torr
H ₂	<1.10 ⁻⁹	Torr
With beam (1A at 3 GeV) N ₂ , CO	6,5.10 ⁻⁹	Torr ¹
H ₂	4,5.10 ⁻⁹	Torr

4. Injection system

Injection efficiency	50 %	
Acceptance	0,5	mrاد cm
Energy spread	±0,5%	
Injection time at about 1,5 GeV		
Electrons	2,6	sec/A
Positrons	150	sec/A

5. Beam parameters at 1,5 GeV and 3 GeV

	1,5 GeV		3 GeV	
Design luminosity	9 · 10 ³²	cm ⁻² sec ⁻¹	1 · 10 ³²	cm ⁻² sec ⁻¹
Beam current	2×6	A	2×0,9A	
Number of particles	2×3,7 · 10 ¹³		2×5,6 · 10 ¹²	
Bunch population number	1		4	
Half crossing angle at interaction point	14	mrاد	6	mrاد
Synchronous phase	1°		16°	
Peak rf voltage per ring	3,4	MV	3,5	MV
Radiation loss	2×228	kW	2×550	kW
Damping times				
Betatron oscillation	80	msec	10	msec
Synchrotron oscillation	37	msec	4,6	msec
Energy spread	0,54	MeV	2,1	MeV
Bunch length (2σ _L)	1,3	cm	3,8	cm
Beam life due to quantum fluctuations	>10 ¹⁰ h		2,6.10 ⁹	h
Beam life due to bremsstrahlung on residual gas	3,9	h	9	h
Beam life due to bremsstrahlung on the other beam at design luminosity	86 h		100	h

"natural" beam emittance		
horizontal	1.10^{-2} mradcm	$4.0.10^{-2}$ mradcm
vertical	$4.5.10^{-5}$ mradcm	$9.3.10^{-5}$ mradcm
"natural" beam dimensions at interaction point		
half beam width (σ_x)	100 μm	200 μm
half beam height (σ_z)	6,7 μm	3,1 μm
Beam emittance required for design luminosity		
horizontal	$3.2.10^{-2}$ mradcm	$4.0.10^{-2}$ mradcm
vertical	$1.2.10^{-2}$ mradcm	$1.0.10^{-4}$ mradcm
Beam dimensions required for design luminosity at interaction point		
half beam width (σ_x)	180 μm	200 μm
half beam height (σ_z)	110 μm	>10 μm

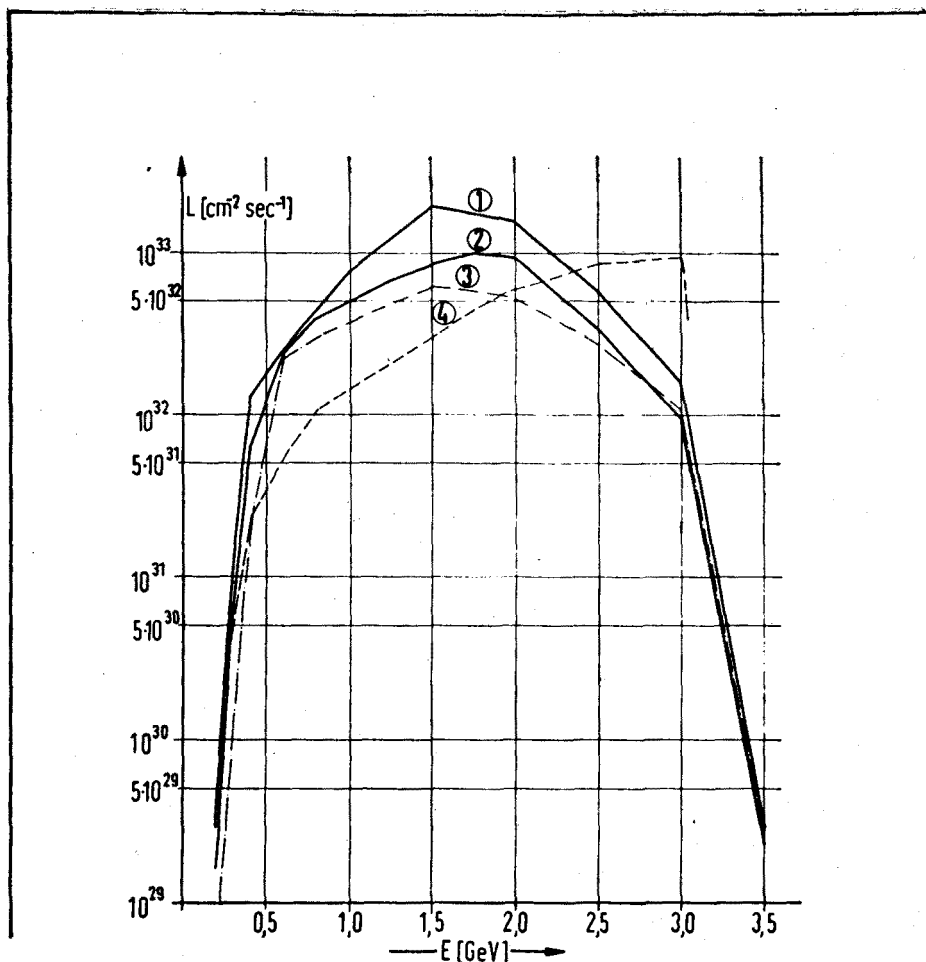


Fig. 1. Vertical Crossing; $12 \text{ mrad} \leq \delta \leq 28 \text{ mrad}$; $\beta_x \geq 0.025 \text{ m}$; $\beta_z \geq 0.1 \text{ m}$
 2. " $12 \text{ mrad} \leq \delta \leq 28 \text{ mrad}$; $\beta_x = 0.1 \text{ m}$; $\beta_z = 0.1 \text{ m}$
 3. Horizontal Crossing; $\delta = 200 \text{ mrad}$; $\beta_x \geq 0.025 \text{ m}$; $\beta_z = 0.1 \text{ m}$;
 4. Space Charge compensated one bunch $\delta = 0 \text{ mrad}$; $\beta_x \geq 1.0 \text{ m}$;
 $\beta_z = 0.3 \text{ m}$

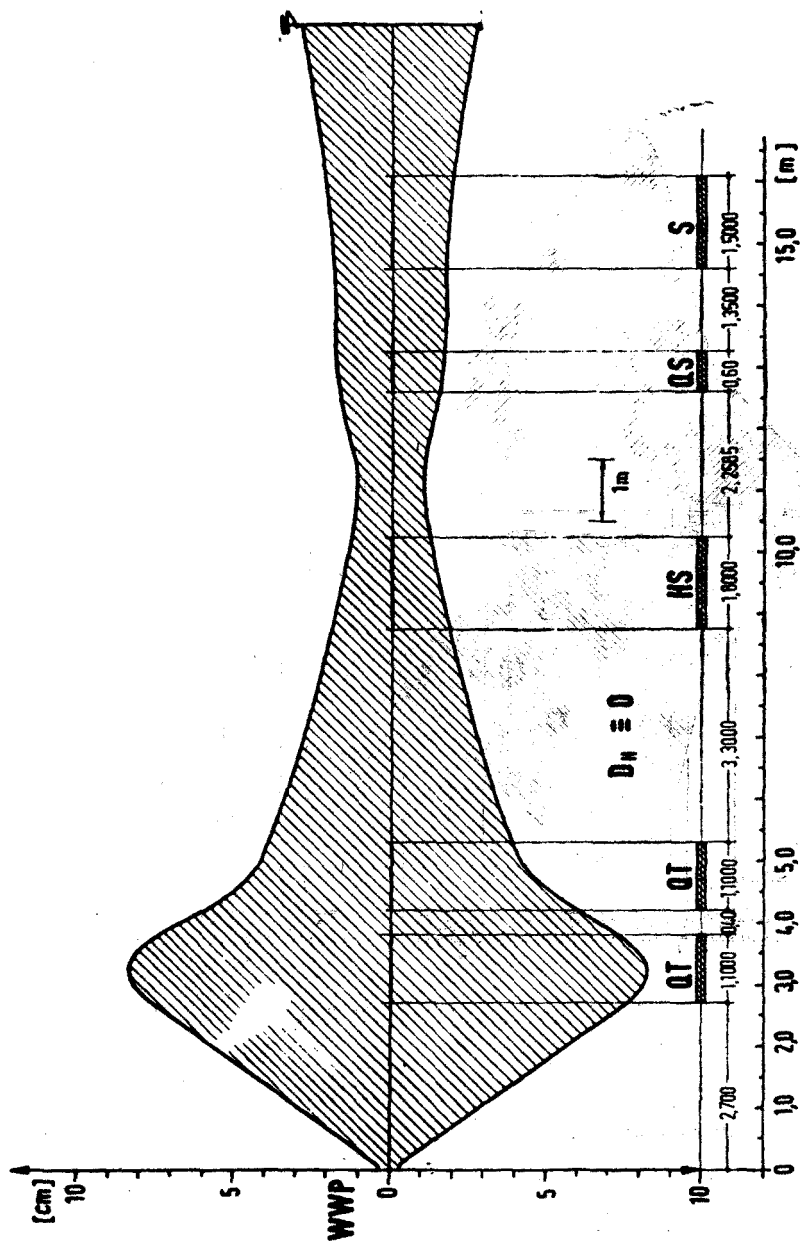


Fig. 2a Horizontale Enveloppe in der Wechselwirkungszone

WWP = Wechselwirkungspunkt

Q = Quadrupolmagnet

S = Septummagnet

HS = Hilfsseptummagnet

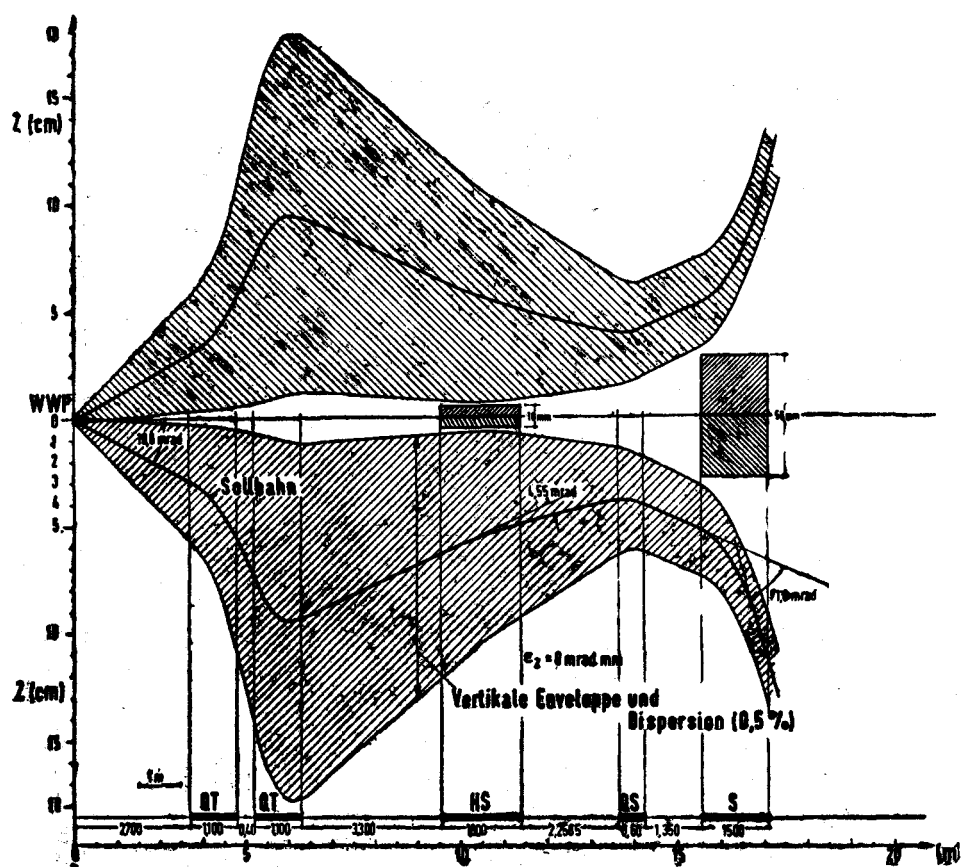


Fig. 2b Vertikale Strahltrennung

WWP=Wechselwirkungspunkt

QT=Quadrupolmagnet

S=Septummagnet

HS=Hilfsseptummagnet

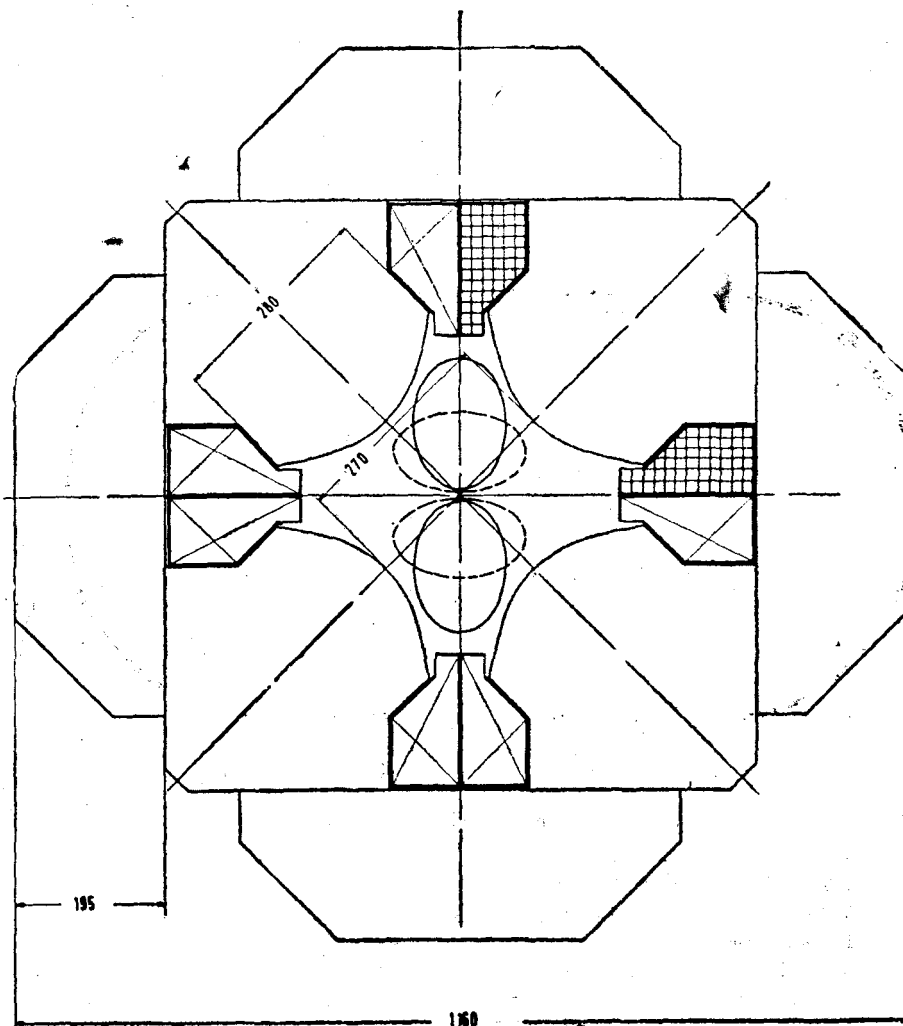


Fig. 3 Quadrupol Typ QT

Technische Daten (3 GeV)

Feldgradient 0,7 KT/cm

magnetische Länge 1100 mm

Stromstärke 940 A

Spannung 100 V

Leistung 100 KW

Gewicht 8 t

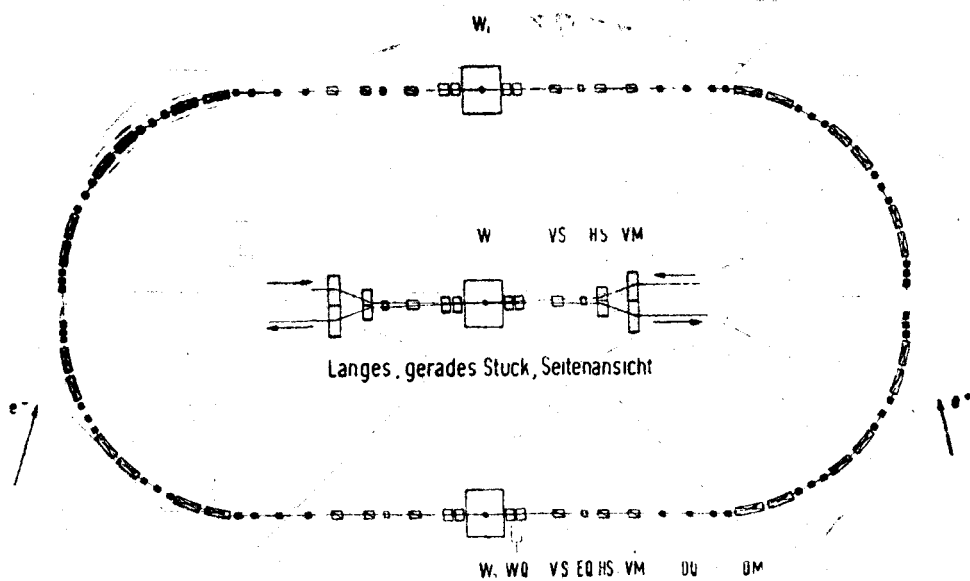


Fig. 4a Magnetstruktur Speicherring

- W—Wechselwirkungspunkt
- DM—Doppel-Ablenkmagnet
- VM—Doppel-Ablenkmagnet (vertikal)
- DQ—Doppel Quadrupol,
- WQ—Einzel Quadrupol, gr. Apertur
- EQ—Einzel-Quadrupol, kl. Apertur
- VS—Vorseptum
- HS—Hauptseptum

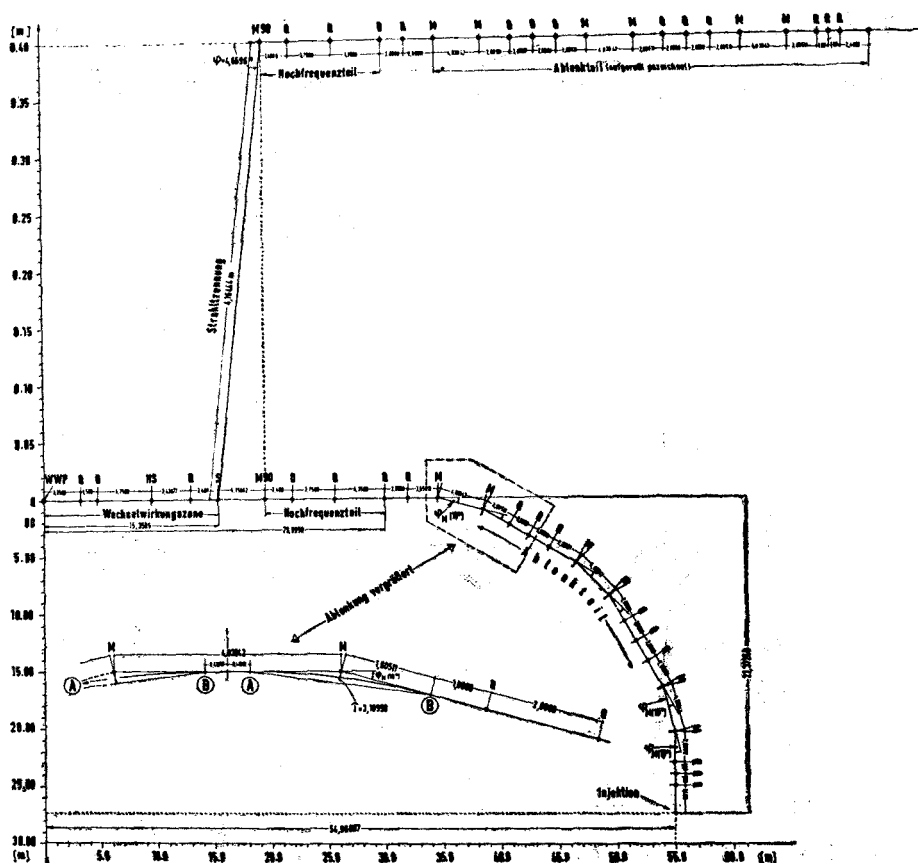


Fig. 4b

WWP—Wechselwirkungspunkt

S—Septum-Magnet

HS—Hilfseptum-Magnet

Q—Quadrupol-Magnet

M—Ablenkmagnet

M90— Ablenkmagnet vertikal

A, B—Die Punkte A, B bezeichnen die Sollbahn am Anfang und Ende des idealisierten Ablenkmagneten (hard edge modell)

Maßangaben in Meter

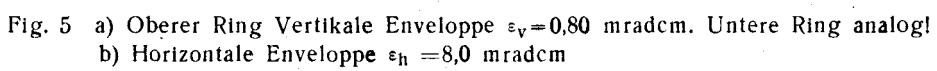


Fig. 5 a) Oberer Ring Vertikale Enveloppe $\varepsilon_v = 0,80$ mradcm. Untere Ring analog!
b) Horizontale Enveloppe $\varepsilon_h = 8,0$ mradcm

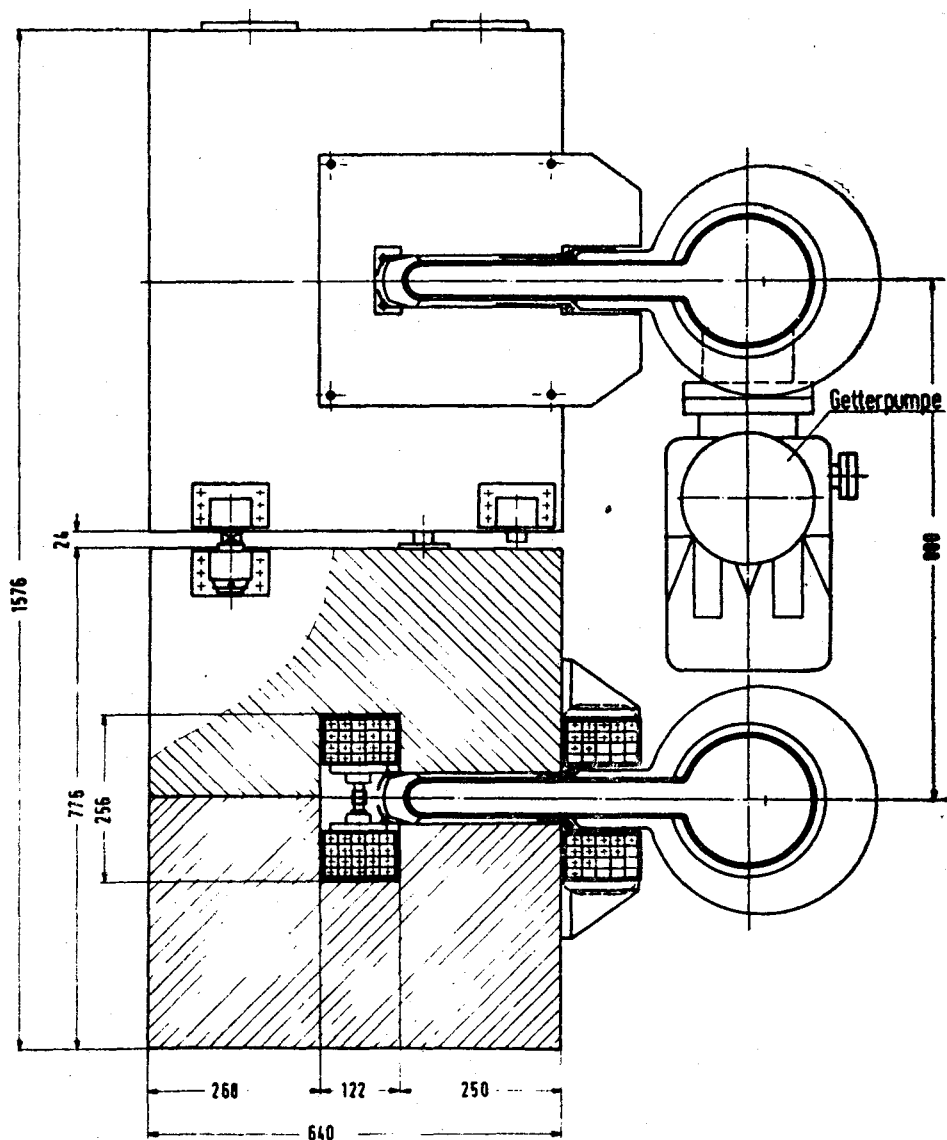


Fig. 6 Doppel-Ablenkmagnet. Technische Daten für den Einzelmagneten

Strahlenenergie	3 GeV	4.5	GeV
Feldstärke im Luftspalt	8.2	12,3	KT
Magnetische Länge	3190	3190	mm
Stromstärke	1280	2000	A
Spannung	23,5	36,6	V
Leistung	30	73	KW
Gewicht (O. K mmer)		11,5	t

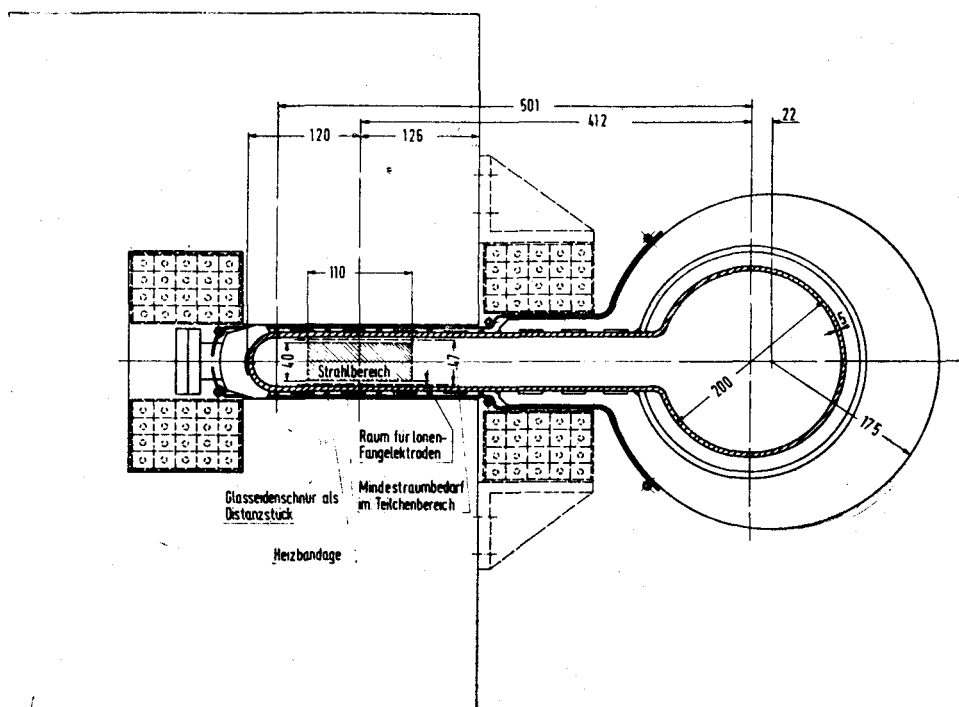


Fig. 7 The Stainless Steel Vacuum Chamber

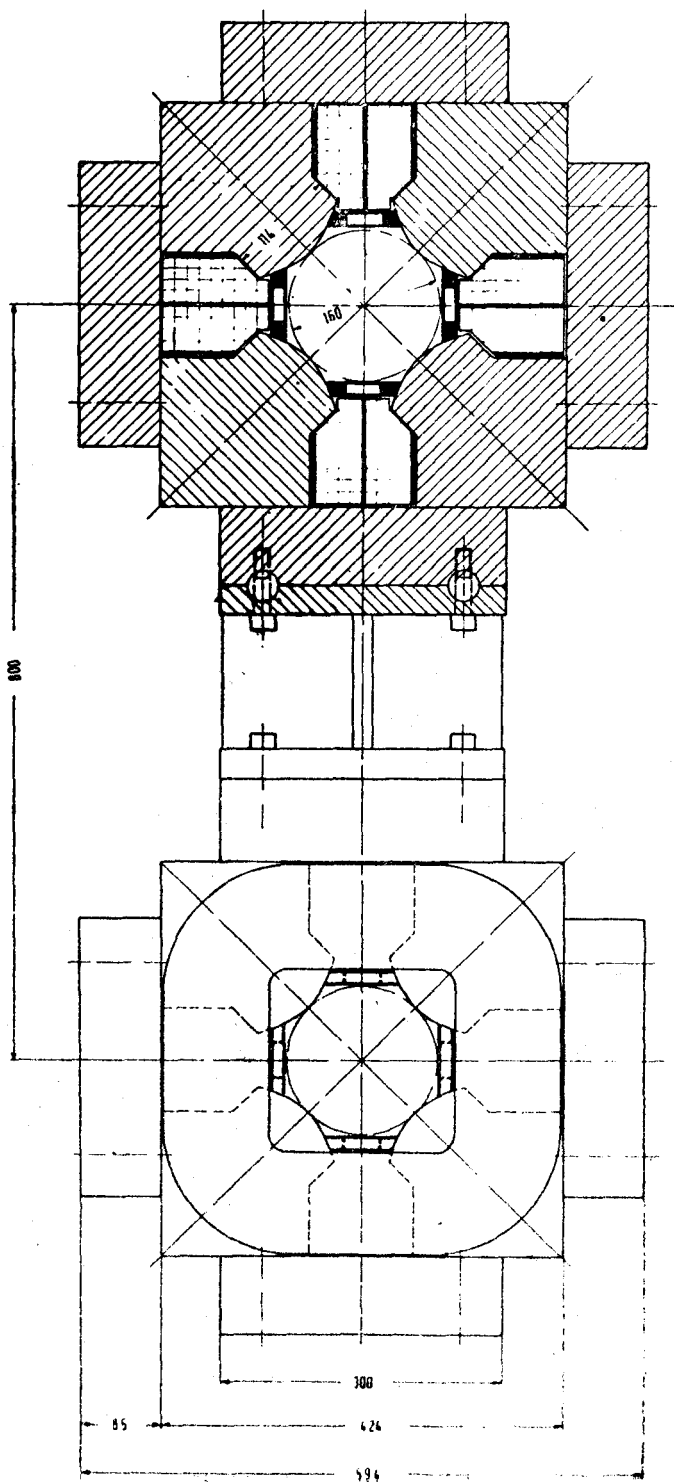


Fig. 8. Doppel-Quadrupol

Technische Daten für den Einzelmagneten	
Strahlenenergie	3 GeV 4,5 GeV
Feldgradient	0,9 1,35 KT/cm
Magnetische Länge	600 600 mm
Stromstärke	740 1110 A
Spannung	38 57 V
Leistung	23 63 KW
Gewicht	2,8 t

Fig. 9. Vakuum-Prototyp-Periode für Speicherring

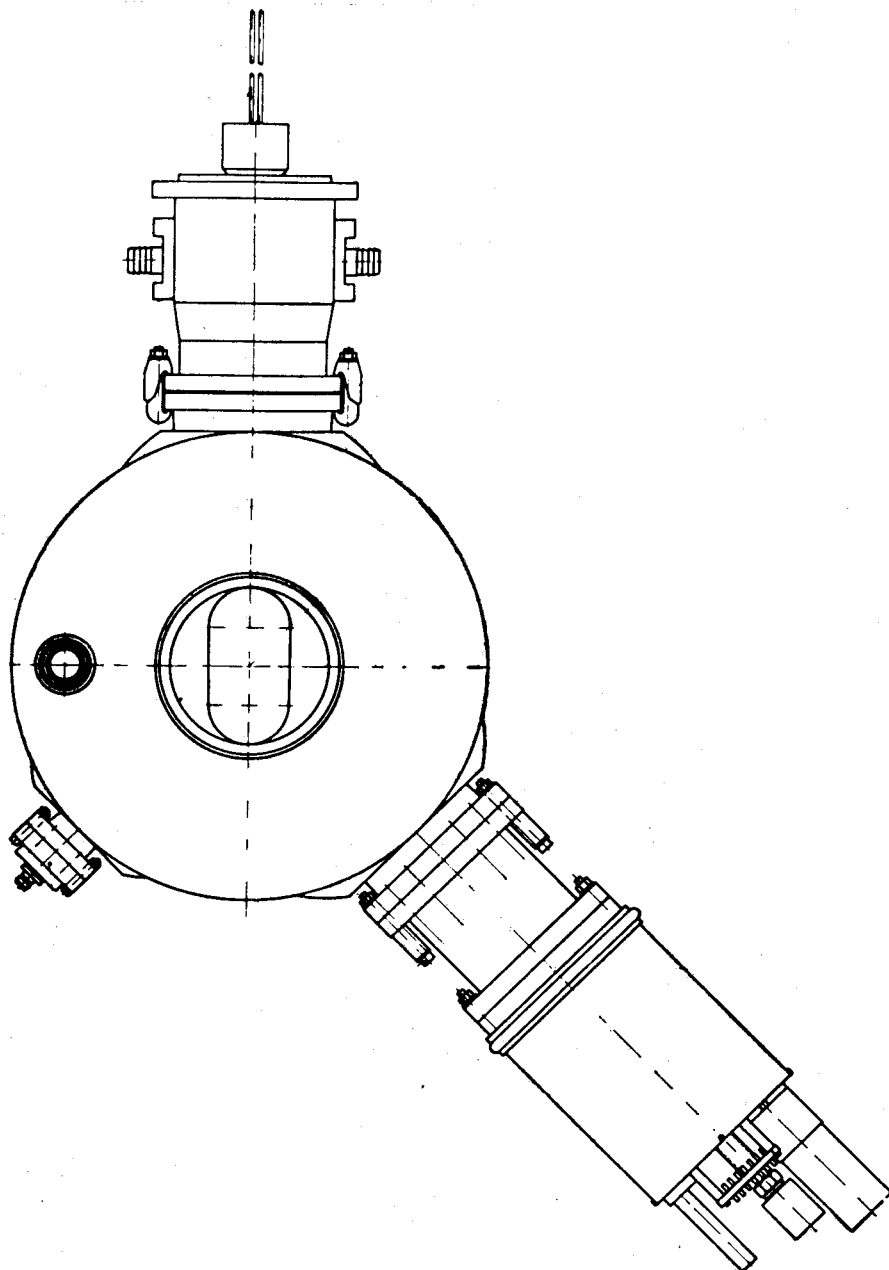


Fig. 10. The axial view of the cavity

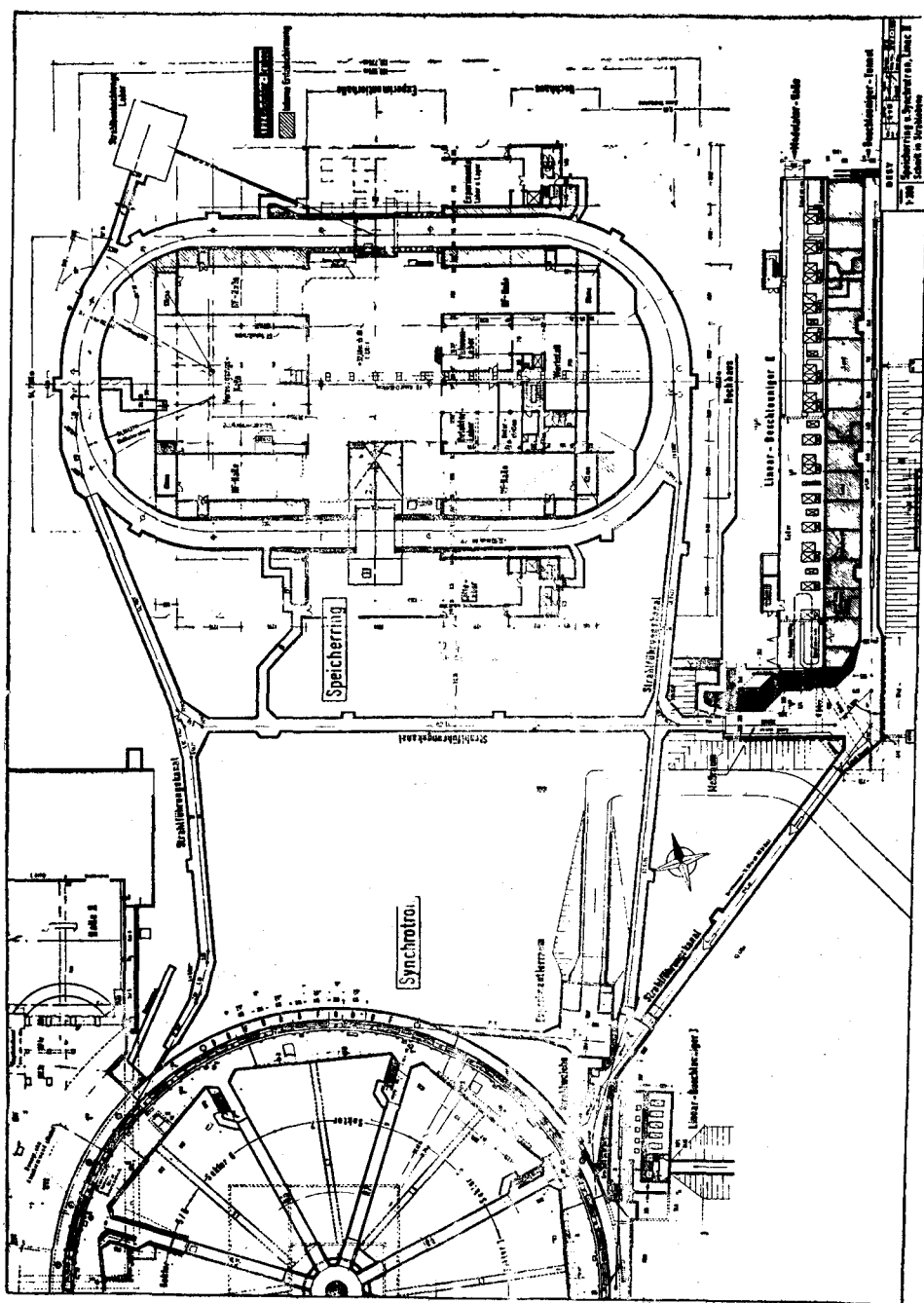


Fig. 11. The site layout

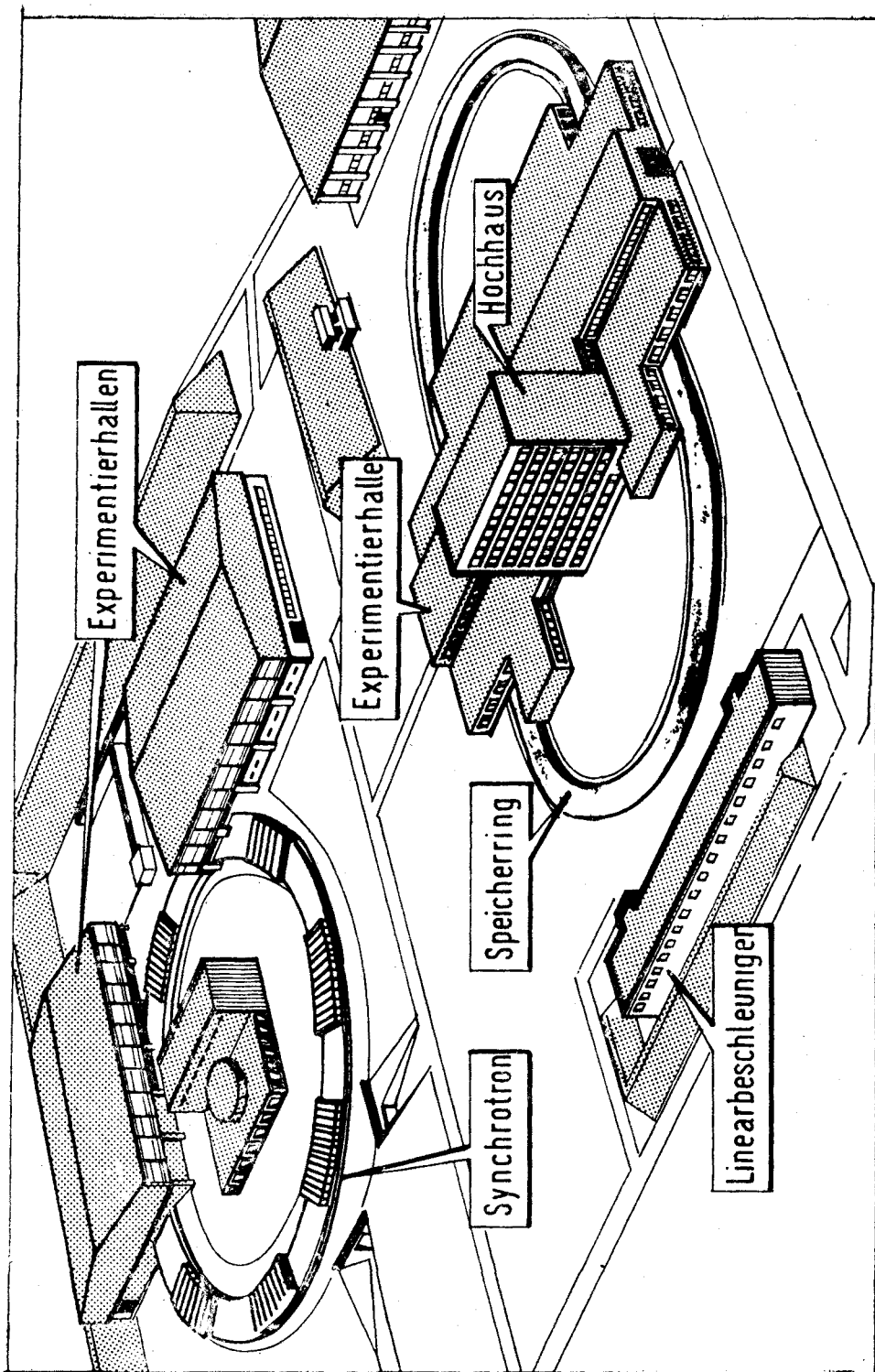


Fig 12. The artist's view of the buildings

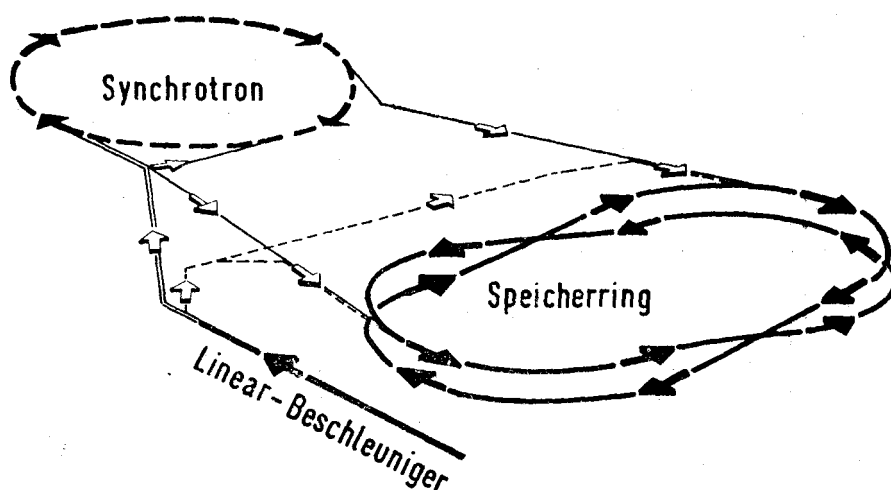


Fig. 13. The beam paths.

ДИСКУССИЯ

Auld: How much steering can be done with correction coils shown before the beam quality is affected?

Steffen: The correction coils are only intended to minimize closed orbit distortions due to misalignments of quadrupoles; the maximum dipole field for correction is 50 Gauss.