NPA/Int. 62-12
Meyrin, 24th October 1962

AN EJECTED BEAM TOWARDS FRANCE

1. General

An ejected beam in the direction of the site over the french border may be useful for storage rings, a separate experimental area for neutrino experiments, or other major extensions of experimental facilities. A beam which largely emerged by analogies with the South Hall beam is described below.

2. Choice of location

Since the long straight sections in the western part of the P.S. are occupied by R.F. cavities and inflector equipment, the ejection magnet that (after excitation of betatron oscillations) makes the beam leave the PS must be split and accommodated in two successive short straight sections. The locations must then be chosen for minimum interference with the functioning of the P.S. The following three possibilities might be considered (see fig. 1) :

	location	required modification of P.S.
1	S.S. 17 + S.S. 18	replacement of 2 pick-up electrodes
2	S.S. 23 + S.S. 24	" " 1 pick-up electrode " " 1 sextu-and-octupole lens turning unit 24 modif. of inflector equipm. near unit 25
3	S.S. 33 + S.S. 34	replacement of 1 pick-up electrode " " 1 sextu-and-octupole lens

PS/3554

Taking account of both beam direction and interference, alternative 1 would appear to be preferable. This location (as well as S.S. 33/34) would have the further advantage of being at a distance equal to $\lambda/4$ (1 + 2 n) from the normally foreseen kicker magnets in S.S. 57 and 97. A kicker magnet in the next possible location, S.S. 13 (at present equipped with a pick-up electrode) could then probably be dispensed with.

Turning the two magnet units could most easily be done by exchanging them with units 22 and 23, and would then not require any major modifications of material.

The following data refer to this alternative, though with minor modifications, they will be applicable to others as well.

3. Required ejection and beam transport equipment

We are concerned here only with the extraction of ~~the beam after it has~~ been excited by either a "fast" kicker magnet or a "slow" resonant method to hit the gap of a septum magnet.

To produce an ejected beam clear of the yoke of magnet unit 20 two magnets (S 1 and S 2) are necessary (see fig. 2). A first septum magnet S 1 would be located in a vacuum tank in S.S. 17. It would be moved into the machine aperture by a hydraulic jack system. An inflector-type vacuum chamber would be mounted in unit 18 and be terminated in the enlarged part by a foil window. A second septum magnet S 2 would be located in air in S.S. 18. A large enough deflection could be obtained by an approximately 45 cm long magnet, so that space would be left for a horizontally focusing quadrupole lens Q 1 which matches the beam into a subsequent AG channel.

Bending magnets B 1 and B 2 are used to deflect the beam clear of existing walls and of linac equipment, and to make it slope upwards such as to arrive at a convenient level at the new site.

All magnetic components could be of a design similar to the South Hall beam.

4. The trajectory

The bending magnets S 1 and S 2 of the extraction system would have to be designed for a bending length of

0.900 m (S 1) and 0.450 m (S 2)

and a flux density of

$$1.5 \frac{Wb}{m^2} \quad (S\ 1 \text{ and } S\ 2)$$

For the external transport system, two sets of bending magnets (B 1 and B 2) would have to be foreseen, each having a bending length of

2.88 m at a flux density of 1.5 Wb/m^2

and giving a slope of

50 mrad

B 2 would bend in the vertical direction

With these magnets one obtains a beam the axis of which is given by the following coordinates (referred to the P.S. rectangular coordinate system) :

Point A (at the beginning of mu 19)	$X = 936.92$ m
	$Y = 1091.61$ m
	$\varphi = 2.5382$ rad
Point B (middle of B 1)	$X = 934.13$ m
	$Y = 1021.53$
	$\varphi = 2.4882$ rad
Point C (middle of B 2)	$X = 929.00$ m
	$Y = 1025.46$ m
	$\varphi = 2.4882$

The horizontal projection of the beam axis is given by

$$Y + 0.7655 \cdot X - 1736.64 = 0$$

The smallest distance d between point S (edge of the wall pillar having the coordinates $X_S = 922.90$; $Y_S = 1030.03$) and the beam axis is :

$$d = 0.11 \text{ m}$$

With the assumed deflection produced by B 2, the beam will pass at a vertical distance e above the vacuum chamber of the linac which is equal to

$$e = 0.78 \text{ m}$$

For details of the computation compare App. 1

5. Beam optics

The optical behaviour of the beam going through MU 17, SS 18, MU 18, SS 19 was calculated at eight points (see fig. 3), starting from the following assumptions about the characteristics of the fast ejected beam :

	largest half width	greatest slope
median plane	$X_{max} = 7.1$ mm	$X'_{max} = 0.32$ mrad
vertical plane	$Y_{max} = 4.3$ mm	$Y'_{max} = 0.34$ mrad

From the Mercury programme 193 p 5 the following partial transfer matrices can be computed :

	from I to IV	from V to VIII
median plane	$\begin{pmatrix} 0.72068 & 5.5941 \\ -0.016614 & 1.2565 \end{pmatrix}$	$\begin{pmatrix} 1.6672 & 7.25068 \\ 0.18795 & 1.4146 \end{pmatrix}$
vertical plane	$\begin{pmatrix} 1.2156 & 5.2426 \\ -0.02718 & 0.7043 \end{pmatrix}$	$\begin{pmatrix} 0.43677 & 4.8540 \\ -0.14860 & 0.6260 \end{pmatrix}$

The gradient of Q_1 has been chosen such that the width of the beam is smaller than 3.0 cm at every point in both planes with the above input data.

This limitation is satisfied by a gradient

$$G = 28.5 \text{ Wb/m}^3$$

With this gradient for Q_1 one obtains the following transfer matrices for the total system :

$$\text{median plane} \quad \begin{pmatrix} 0.04086 & 11.09962 \\ -0.08450 & 1.34340 \end{pmatrix}$$

$$\text{vertical plane} \quad \begin{pmatrix} 1.4321 & 10.5735 \\ -0.05971 & 0.21537 \end{pmatrix}$$

Considering the C.P.S. as a system of many diaphragms, we assume that the phase plane representation of our beam is well approximated by an ellipse. In fig. 4 these ellipses are given for the beam entering and leaving the optical system (points I and VIII) defined above. From these ellipses the further transport system can be computed once the utilisation of the beam is defined.

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/fv

<u>Distribution</u> : (open)

Scientific staff of N.P.A.

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Appendix 1

1) The axis of a beam travelling through a bending magnet has a circular shape. Distance y and slope y' with respect to the incoming beam are for small angles given by :

$$y = \frac{l}{z} \cdot y'$$

$$y' = \frac{l \cdot B}{R_o \cdot B_o}$$

l : bending length of the magnet (m)

B : flux density $\left(\frac{Wb}{m^2}\right)$

$R_o = 70.079$ m

$B_o = 1.186 \ \frac{Wb}{m^2}$

The beam enters S_1 at a maximum of the betatron oscillations, and therefore parallel to the equ. orbit at a distance

$$a = 0.025 \text{ m (betatron amplitude)}$$

The initial values used as input data for the mercury computer (see report PS/Int. EA 59-14) are indicated in fig. 4 a and 4 b.

Because of the splitting of the septum magnet one has to make separated computer calculations for the trajectory through m.u. 17 and m.u. 18.

2. Input data

S.S. 17 : (see fig. 6 a)

$$y'_o = \frac{B \cdot l}{B_o \cdot R_o} = B \cdot \frac{0.900}{83.1} ; \qquad \underline{y'_{o1} = B \cdot 1.08303 \cdot 10^{-2} \text{ rad}}$$

$$y_o = a + 0.550 \cdot y'_o \qquad \underline{y_{o1} = 0.025 + 0.550 \ y'_o \text{ m}}$$

S.S. 18 : (see fig. 6 b)

Notations :

φ : slope in rad with respect to equ. orbit at the end of m.u. 17

ϑ : additional slope due to S 2

$$\vartheta = B_{S2} \cdot \frac{0.450}{83.1} \text{ rad}$$

d' : $d' = d + \varphi \cdot 0.225$

e : additional displacement due to S 2

$$e = 0.875 \cdot (\varphi + \vartheta) = 0.875 \cdot y'_{o2} \ (m)$$

One gets the following input data for m.u. 18 :

$$y'_{o2} = \varphi + \frac{0.450}{83.1} \cdot B_{S2} \qquad \underline{y'_{o2} = \varphi + 0.005415 \cdot B_{S2}}$$

$$y_{o2} = d' + e \qquad \underline{y_{o2} = d + \varphi \cdot 0.225 + 0.875\, y'_{o2}}$$

3) Calculations of the coordinates of the points A, S, and Q (fig. 1 and 2)

S and Q are points representative for the maximum and minimum angle - with respect to the C.P.S. coordinate system - of a beam clear of walls and linac equipment. On account of the inaccuracy of the drawings measurements were made to determine the coordinates of both points.

Point S : (see fig. 5 b)

From the measurements : $a = 3.20$ m

$b = 4.20$ m

and the points m 22, F 19, F 21, (see M.P.S. / Int. ALO 62-3)

one obtains $q = 3.8038$ m

$\varepsilon = 39^{\circ}\ 52.8'$

$\gamma = 48^{\circ}\ 2.1'$

and $\delta = 8^{\circ}\ 9.3'$

Hence

$X_S = X_{F21} - \Delta X = 922.90$ m

$Y_S = Y_{F21} + \Delta Y = 1030.03$ m

Point Q : (see fig. 5 c)

Measurements : $f = 4.43$ m

$g = 7.46$ m

One obtains : $\beta = 36^{o}\ 25'\ 54''$

$\varphi = 51^{o}\ 15'\ 35''$

$\alpha = 14^{o}\ 49'\ 41''$

and $X_Q = X_{m22} - \triangle x = 911.52$ m

$Y_Q = Y_{m22} + \triangle y = 1035.03$ m

Point A : (see fig. 5 a)

A is the end point given by the computer calculation. The output data of the computer with the mentioned flux density of S_1 and S_2 are :

$$y_{o3} = 0.450 \text{ m}$$

$$y'_{o3} = 0.07174 \text{ rad}$$

With

$$\zeta = 38^{o}\ \ 39{,}5'$$

one obtains

$$X_A = F_{19} + \triangle\ x = 936.92 \text{ m} ;$$

$$Y_A = F_{19} - \triangle\ y = 1019.61 \text{ m}$$

4) Trajectory

The slope of the beam axis at point A is

$$\varphi_A = 3.1416 - \zeta\ (\text{rad}) + y'_{o3} = 2.5382 \text{ rad}$$

and the equation of the beam axis is

$$0.56742\ x + 0.82342\ y - 1371.188 = 0$$

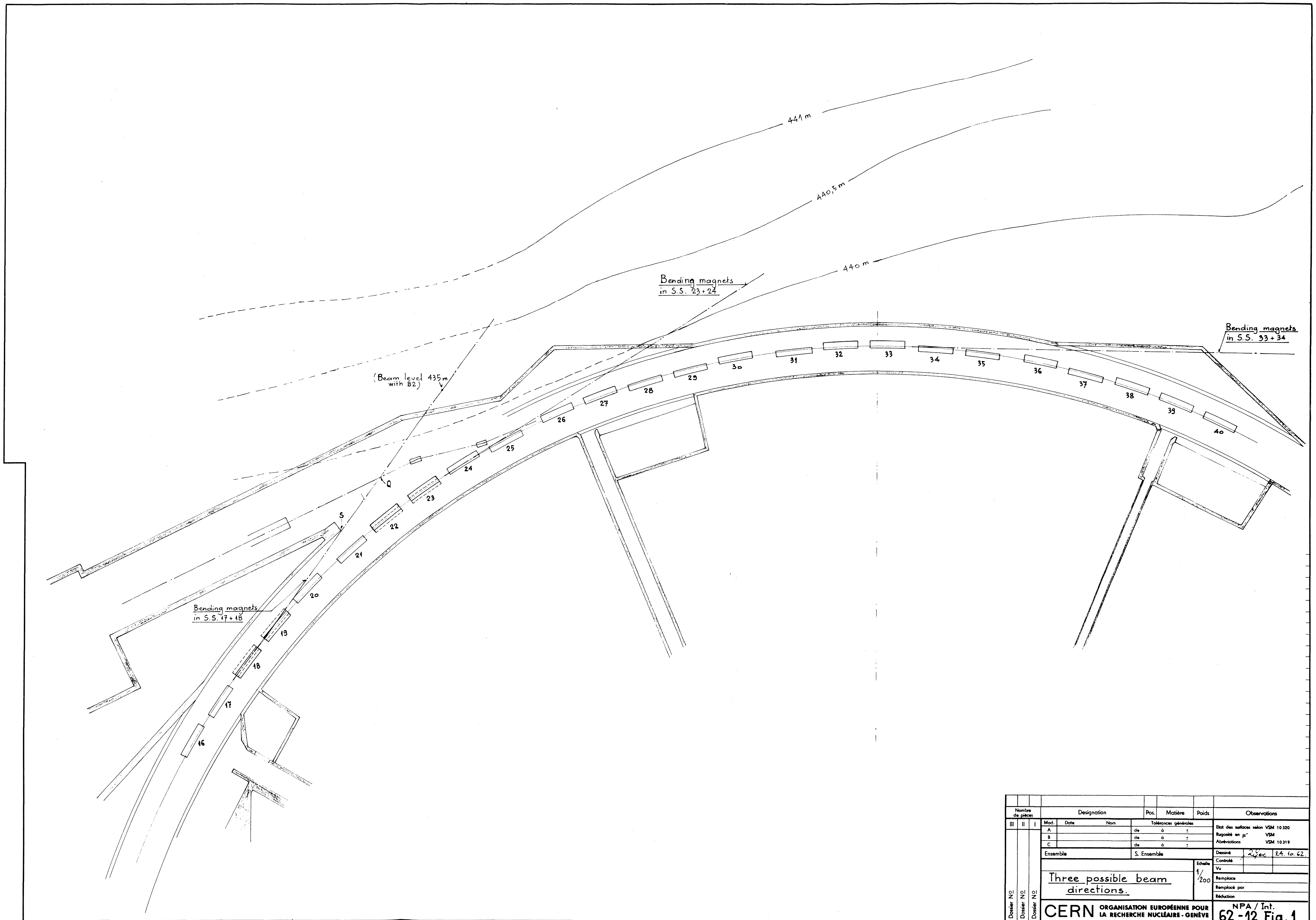
The location of B_1 is chosen such that there is a sufficient distance between this magnet and magnet unit 19.

The bending given by B_1 is equal to 50 mrad. Therefore we get the final slope of the beam axis

$$\varphi_B = 2.4882 \text{ rad}$$

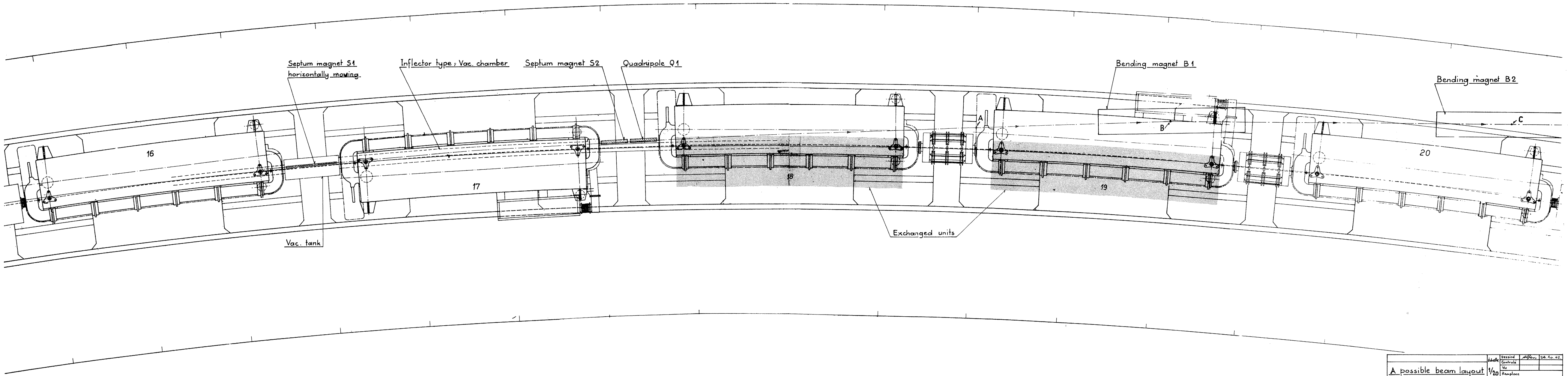
The equation of the beam axis is then given by

$$0.60787\ x + 0.79404\ y - 1378.996 = 0$$



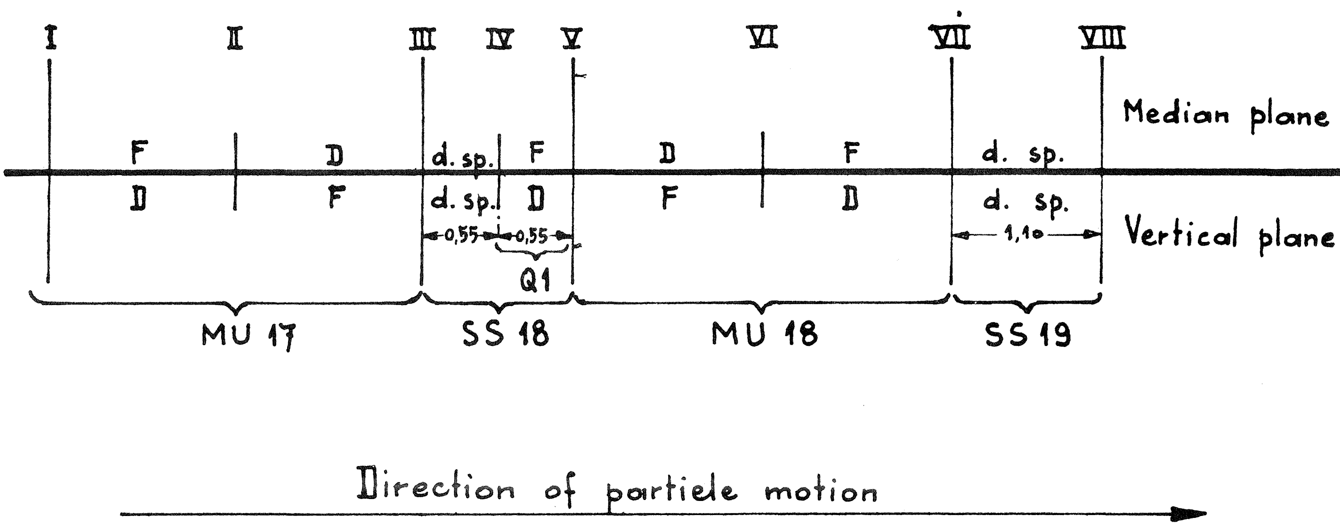
Nombre de pièces			Designation	Pos.	Matière	Poids	Observations
III	II	I	Mod. Date Nom	Tolérances générales			Etat des surfaces selon VSM 10320
			A	de à ±			Rugosité en µ VSM
			B	de à ±			Abréviations VSM 10319
			C	de à ±			Dessiné 24. 10. 62.
			Ensemble	S. Ensemble			Contrôlé
			Three possible beam directions.	Echelle 1/200			Vu / Remplace / Remplacé par / Réduction
Dossier Nº	Dossier Nº	Dossier Nº	CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE				NPA / Int. 62 - 12 Fig. 1

SIS/R/5030



	Échelle	Dessiné		24.10.62.
A possible beam layout	1/20	Controlé		
		Vu		
		Remplace		
		Remplacé par		
		Réduction		
CERN ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE - GENÈVE		NPA / Int. 62-12 Fig. 2		

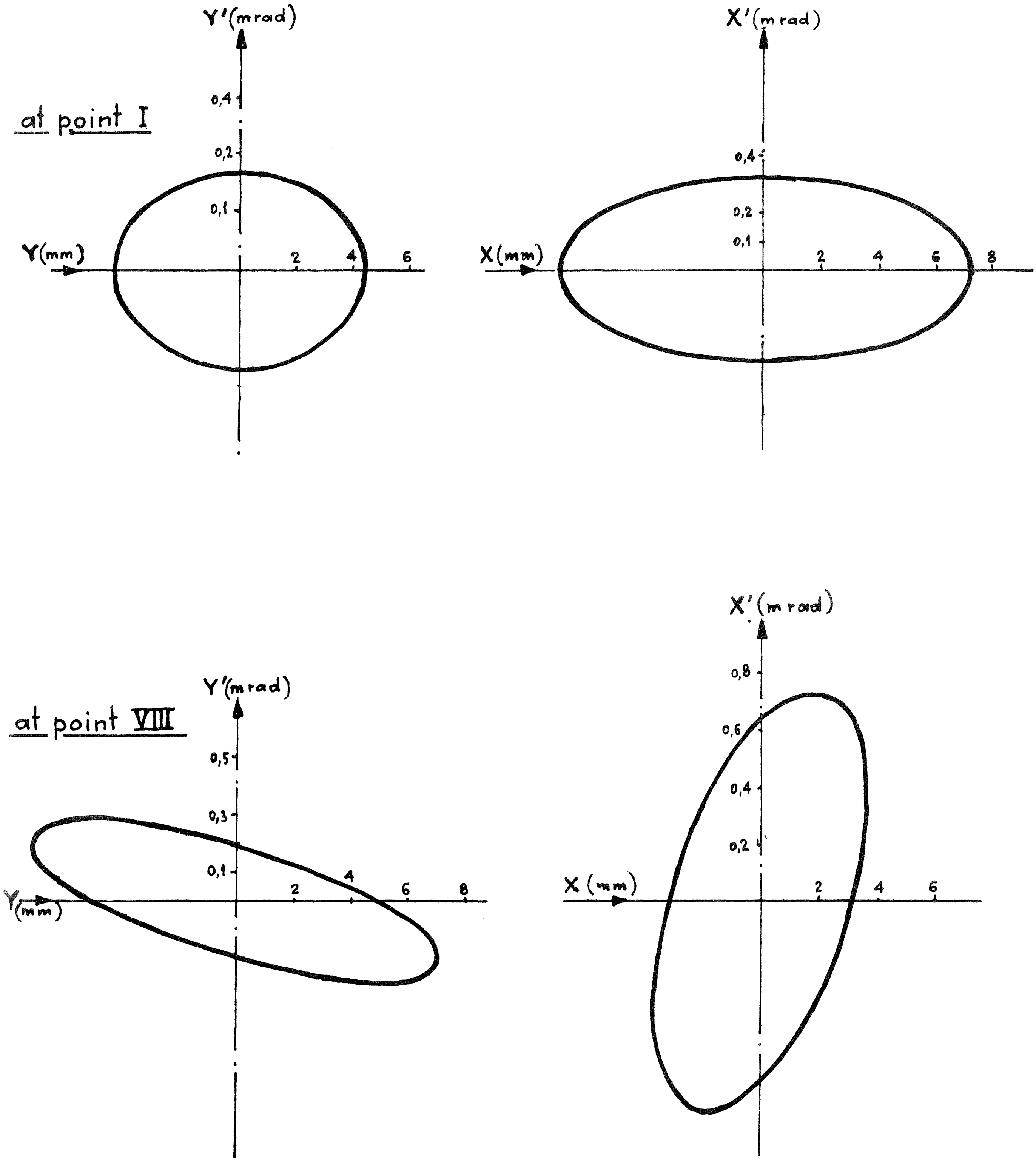
SIS/R/5031



NPA / Int.

62 - 12 Fig. 3

SIS/R/5187



Vertical plane   Median plane

Phase diagramme.

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62 - 12 Fig. 4

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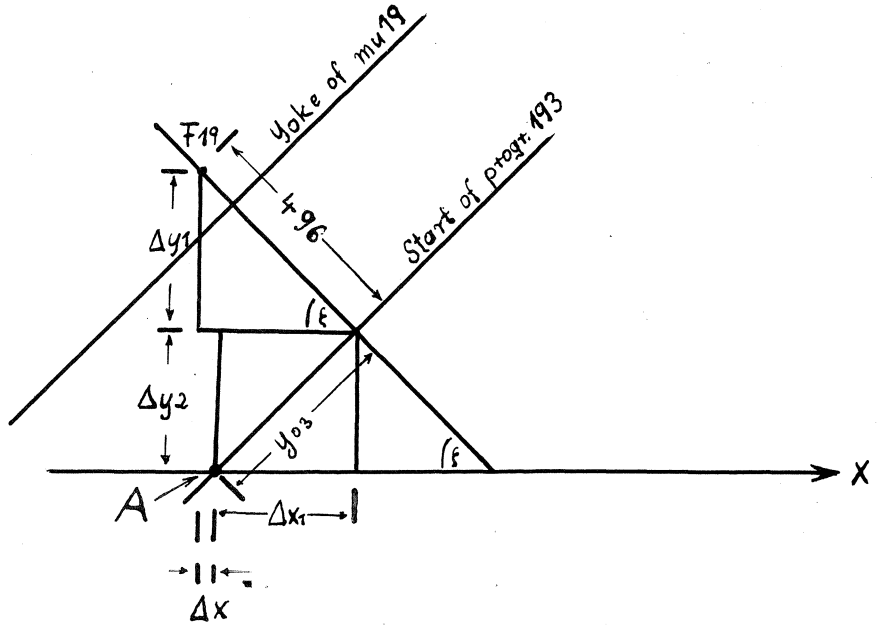
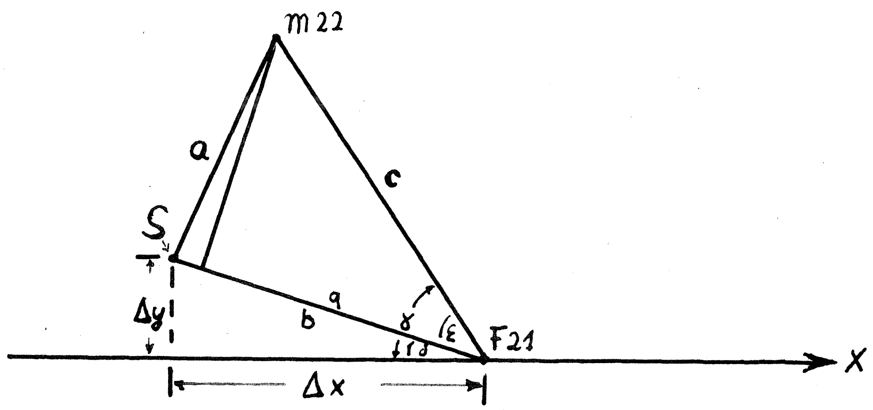
5a


F19
Yoke of mu19
Start of progr. 193
496
Δy_1
Δy_2
ε
y_{03}
A
Δx_1
Δx
X

5b


m22
a
c
S
q
b
γ
ε
δ
F21
Δy
Δx
X

5c

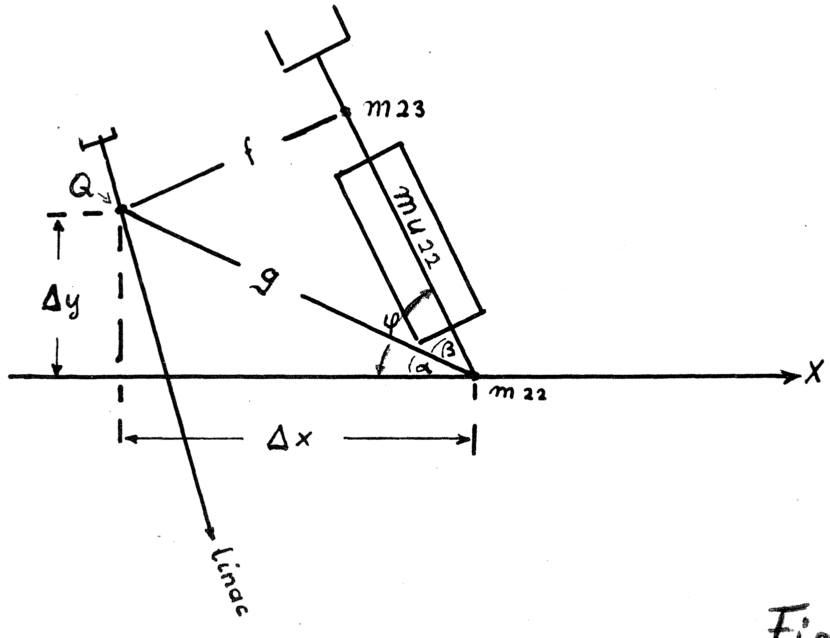

m23
f
Q
mu22
g
φ
β
α
m22
Δy
Δx
X
Linac

Fig. 5

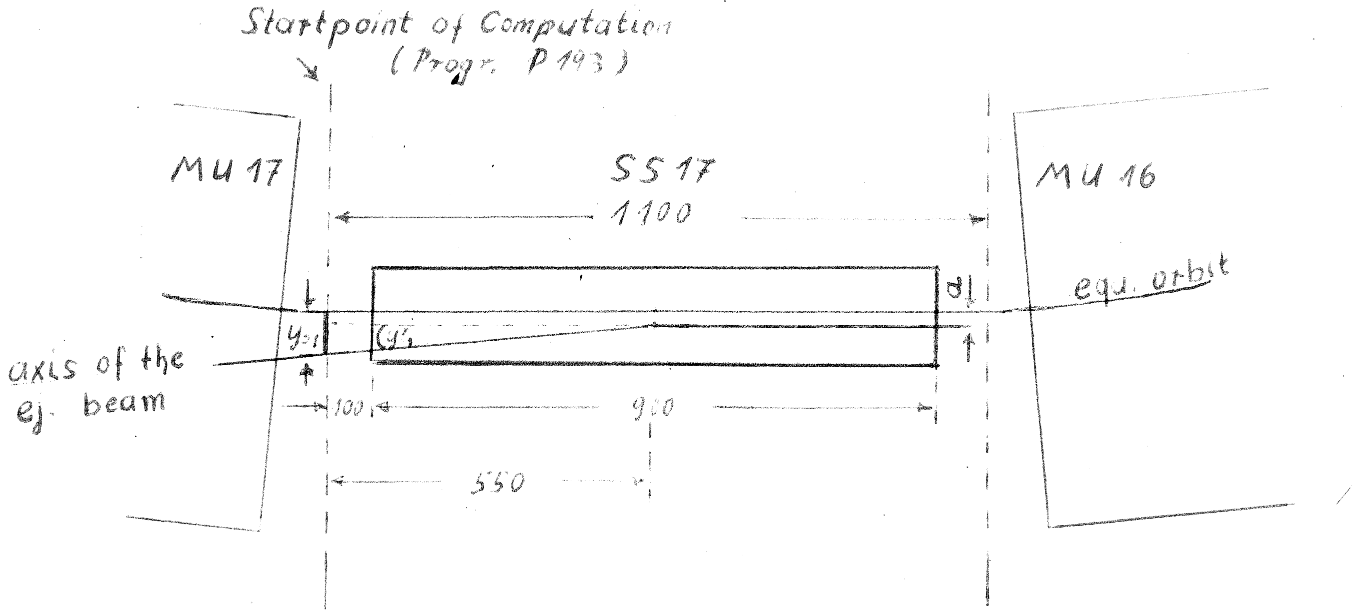


Fig. 6a

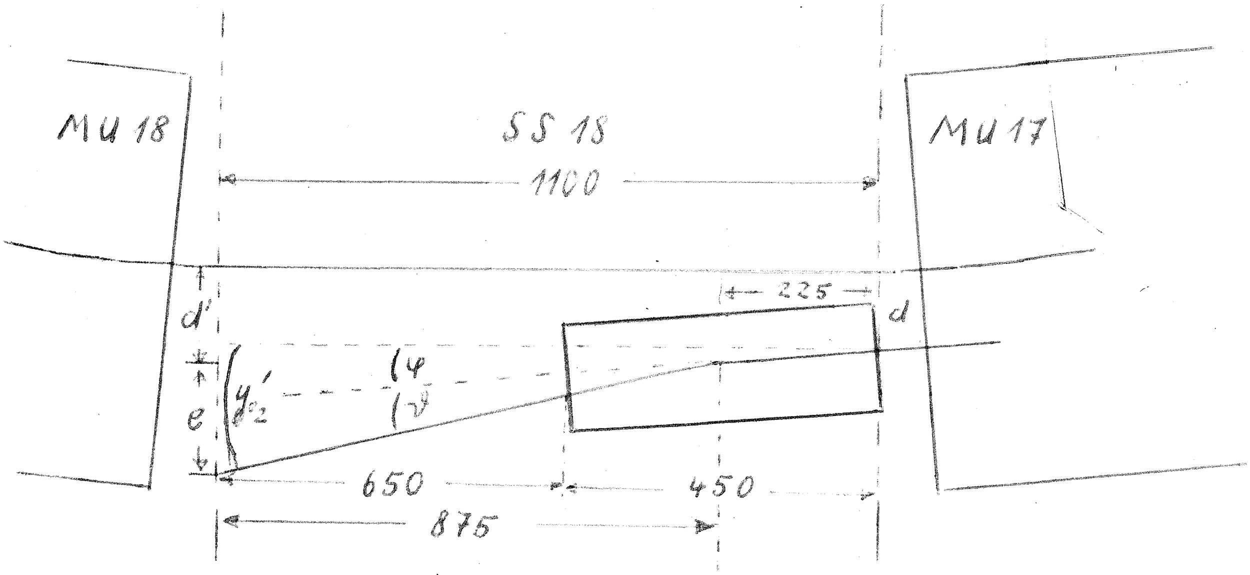


Fig. 6b

Fig. 6: Geometry of magnets in SS 17 and SS 18