PS/AA/AC - 16 August 4, 1983

AC MAGNETS

FOR THE DESIGN REPORT

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INTRODUCTION

The following decisions have been taken :

i) Install P.U. for beam position inside the quadrupoles on condition that the head amplifiers have enough place between coils.

ii) Keep magnet apertures as those defined in note AC-14, but adapt the magnet design to lattice 83-08.
This note gives all magnet parameters used for the design report.

The Annexe 1 shows the AC ring with the corresponding magnet names. The real beam size is shown in Annexe 2 ; however the beam size used to define the magnet apertures includes some margin as follows :

$$\frac{x}{2} = 1.1\ \sqrt{\beta_H \varepsilon_H} \ + \ \alpha_p \ \frac{\delta_p}{p} \ + 5 \sqrt{\frac{\beta_H}{\overline{\beta}_H}}$$

$$\frac{y}{2} = 1.1\ \sqrt{\beta_V \varepsilon_V} \ + \ 5 \sqrt{\frac{\beta_V}{\overline{\beta}_V}}$$

DIPOLE

The design remains the same as the one in note AC-14.

Figure 1 shows the beam sizes in each of 6 dipoles belonging to a quarter of the machine (from lattice 83-08). They fit well with the previous aperture. There are 24 dipoles including a special one.

The sagitta is ± 32 mm ; it is calculated for the momentum

P = 3.5752 GeV/c which is the one of AA injection orbit.
Table 1 gives dipole parameters for the design report.

The copper resistivity used in this design is $1.81 \times 10^{-2}\ \Omega mm^2/m$. According to the real value being greater or smaller, the power dissipation could change by several kW.

Non-linear two-dimensional calculations have been done to determine the pole profile.

The three-dimensional calculations will be done soon in order to find a solution where the natural sextupole component is cancelled and the necessary sextupole component to correct the chromaticity is added.

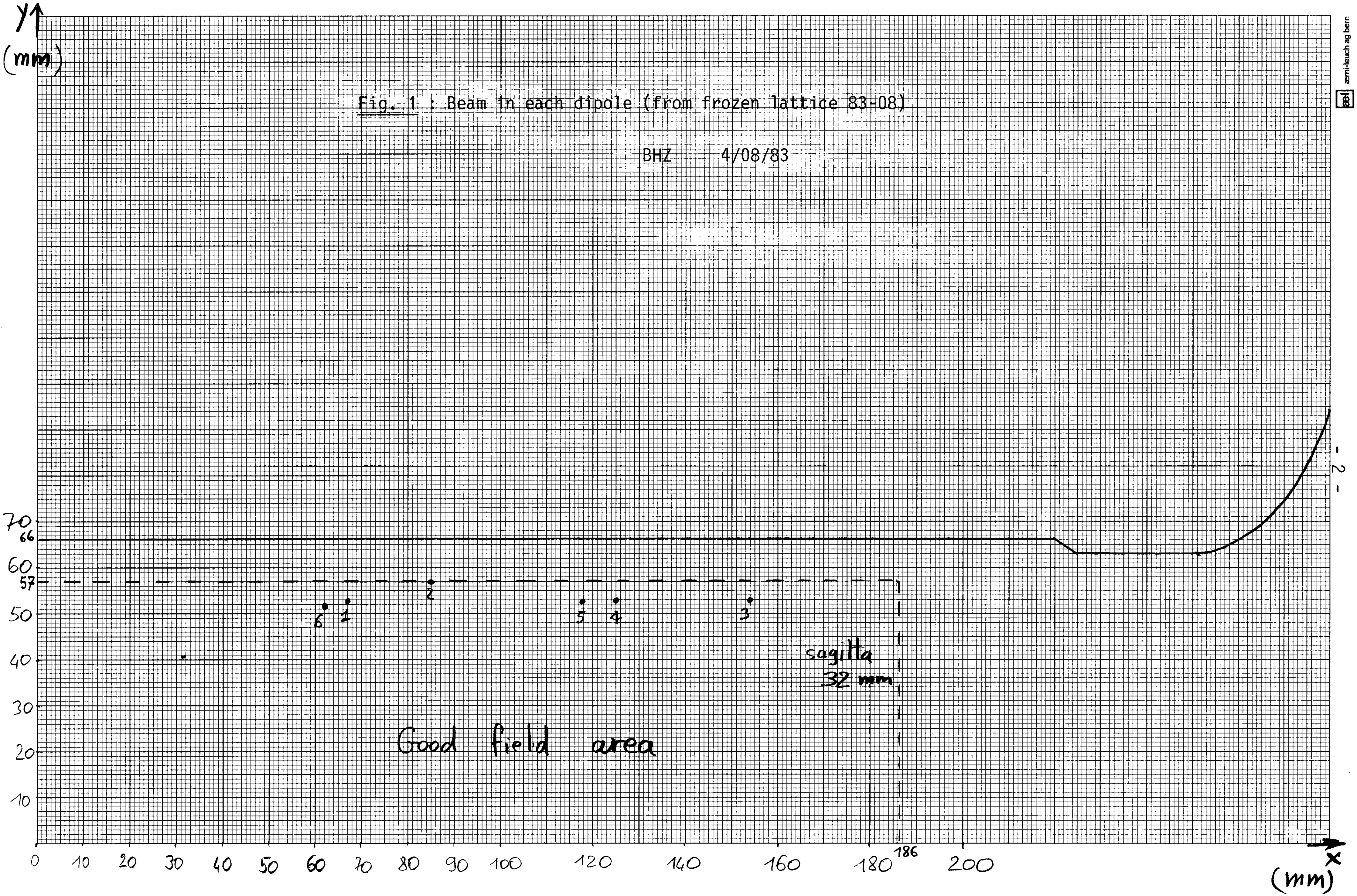


Fig. 1 : Beam in each dipole (from frozen lattice 83-08)
BHZ 4/08/83
Y (mm)
70
66
60
57
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
120
140
160
180
186
200
x (mm)
6
1
2
5
4
3
sagitta
32 mm
Good field area

TABLE I

DIPOLE

Number	24	
Bending angle	261.79	mrad
Field	1.6	T
Eff. length	1.9513	m
Field x eff. length	3.12	T.m
Bending radius	7.455	m
Core length	1.890	m
Gap height	132	mm
Overall length	2 280	mm
Overall width	1 860	mm
Overall height	1 084	mm
Good field width	± 186	mm
Good field height	± 57	mm
Nominal current	1 838	A
Nominal power	71	kW

COIL 1 (2 off) turns	42		COIL 2 (1 off)	12	
Conductor sections	24 x 24	mm^2		28 x 19	mm^2
Current density	3.42	A/mm^2		3.72	A/mm^2
Hole diameter	7	mm		7	mm
Avge length/turn	6.5	m		5.7	m
Temp rise/layer(coil 1)	20	°C	/coil 2	20	°C
Pressure drop/layer	2.6	bar	/coil 2	9.2	bar
Water flow/layer	3.7	l/mn	/coil 2	6	l/mn
Resistance/layer	1.53	mΩ	/coil 2	2.5	mΩ
Water flow per dipole	50.4	l/mn			
Resistance per dipole	20.9	mΩ			
Copper weight	2.611 + 0.293 tonnes				
Steel weight	24.75	tonnes			

Total water flow	72.6	m^3/h
Total power	1.704	MW

QUADRUPOLE

Figure 2 shows the beam sizes in each of 15 quadrupoles belonging to a quarter of the machine (from lattice 83.08).

There are 56 quadrupoles including two specials. The distinction should be made between Narrow and Wide quadrupoles.

According to figure 2 and lattice 83.08, we can deduce that 8 and 10 (F type) should be wides ; however the requested gradient is the same (7.02 T/m) for 8, 10 and 6. Deductions are the same for 7 and 9 (D type) and they should be also wides. The following repartition was adopted :

	Gradient (T/m)	Size (wide or narrow)	Number
Quadrupoles D :	6.08	W	8
	6.08	N	20
Quadrupoles F :	5.81	N	16
	7.02	W	12

Of the 56 quadrupoles, 36 are of one type (QN) and 20 are of another (QW).

For the D quadrupoles, the diameters and turns/pole have been adjusted so that a given current will produce the same gradient in both QDW and QDN.

For the F quadrupoles, where 2 different strength families are requested, two different currents should be adjusted for each family.

The adopted solution uses a TRIM power supply to feed the appropriate current in the 12 Wide focusing quadrupoles.

In conclusion, the QFW and QFN are identical magnets as QDW and QDN (iron and coils) but the current is different in QFW and QFN. Table 2 gives all parameters adapted to these requests.

Figure 3 shows the Wide pole profile with the beam sizes in each corresponding quadrupole.

Figure 4 shows the Narrow pole profile with the beam sizes in each other corresponding quadrupole.

In both types, there is space enough to place a P.U. inside the quadrupole and have 1 cm clearance from the vacuum chamber.

Non-linear two-dimensional calculations have been made to determine the pole profile for the previous quadrupoles.

For these new ones, if no special problems arise for the narrow, some difficulties could be however expected for the focusing wides where the requested gradient gives around 1.6 T at the ends of the pole.

The three-dimensional calculations will be made soon. The need for shimming the quadrupoles should be determined.

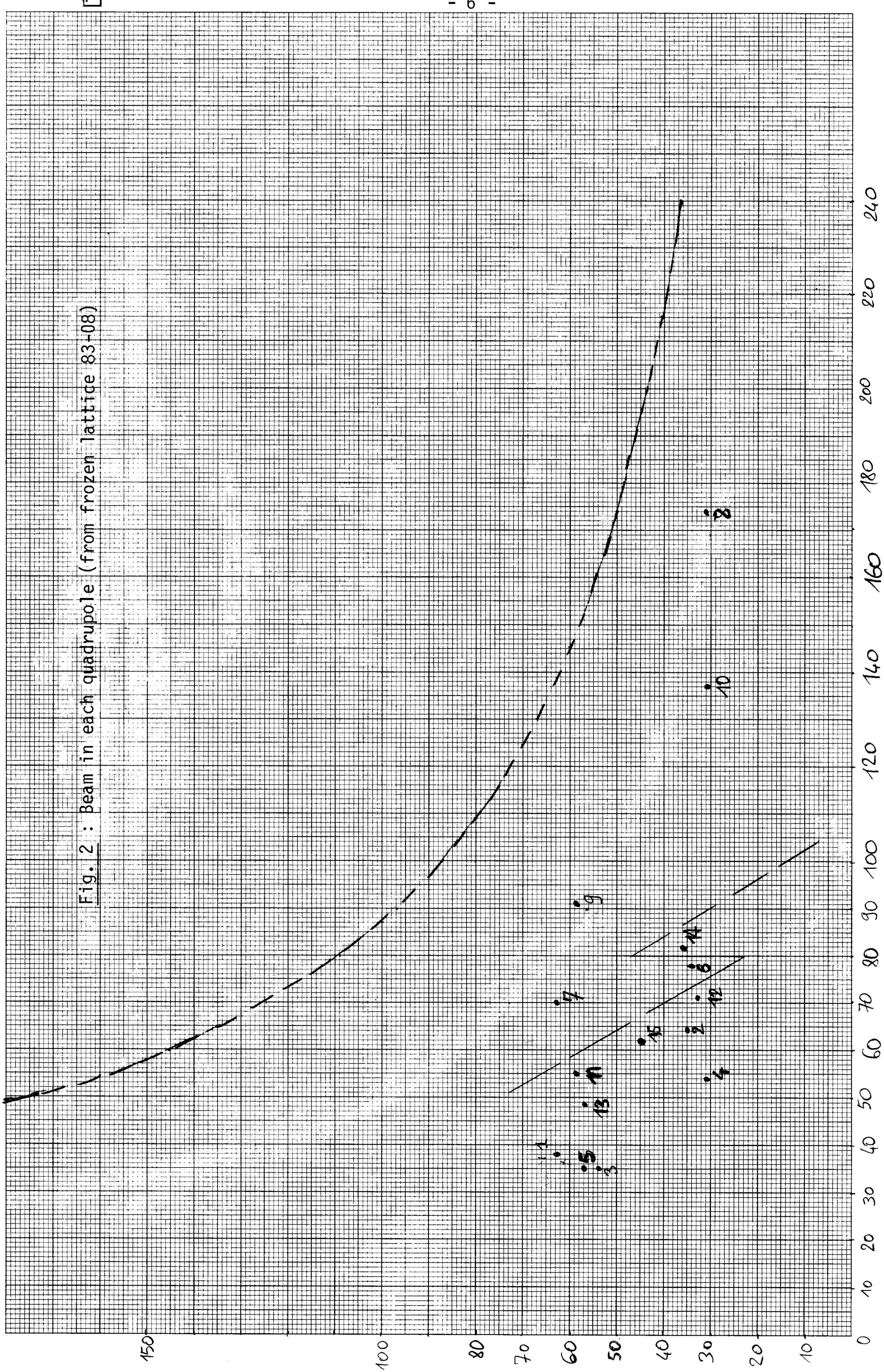


Fig. 2 : Beam in each quadrupole (from frozen lattice 83-08)

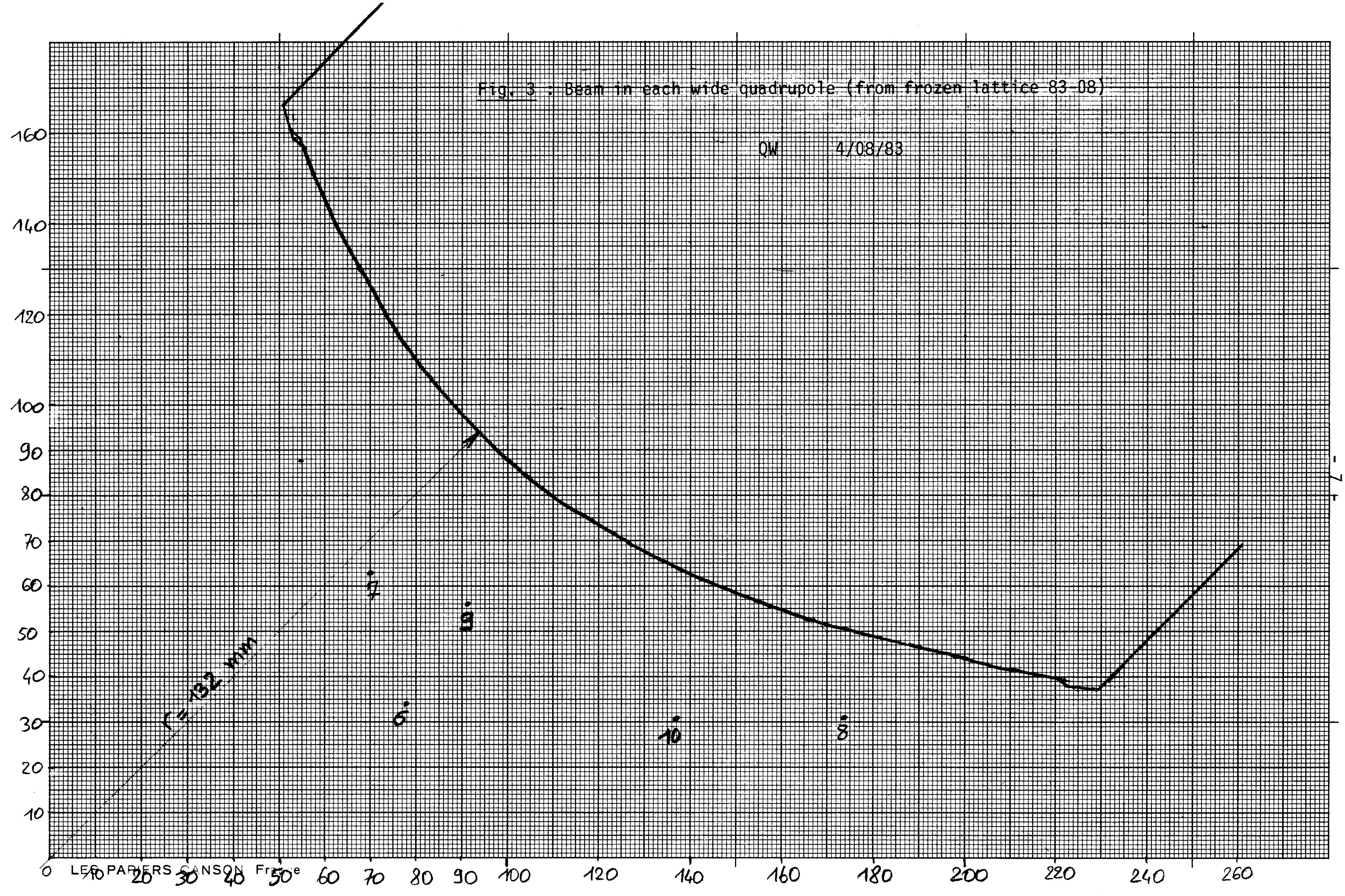


Fig. 3 : Beam in each wide quadrupole (from frozen lattice 83-08)

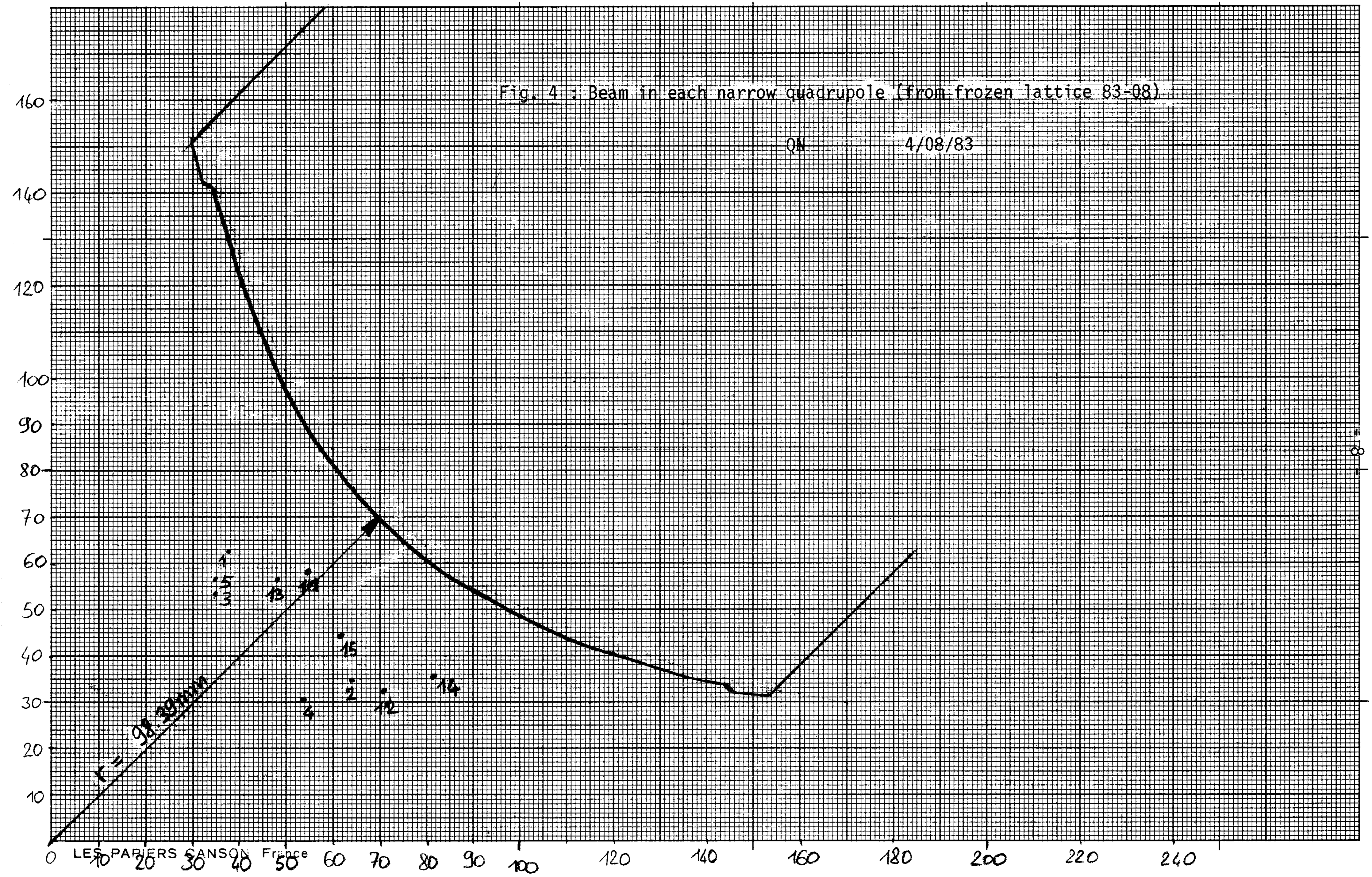


Fig. 4 : Beam in each narrow quadrupole (from frozen lattice 83-08)

TABLE II

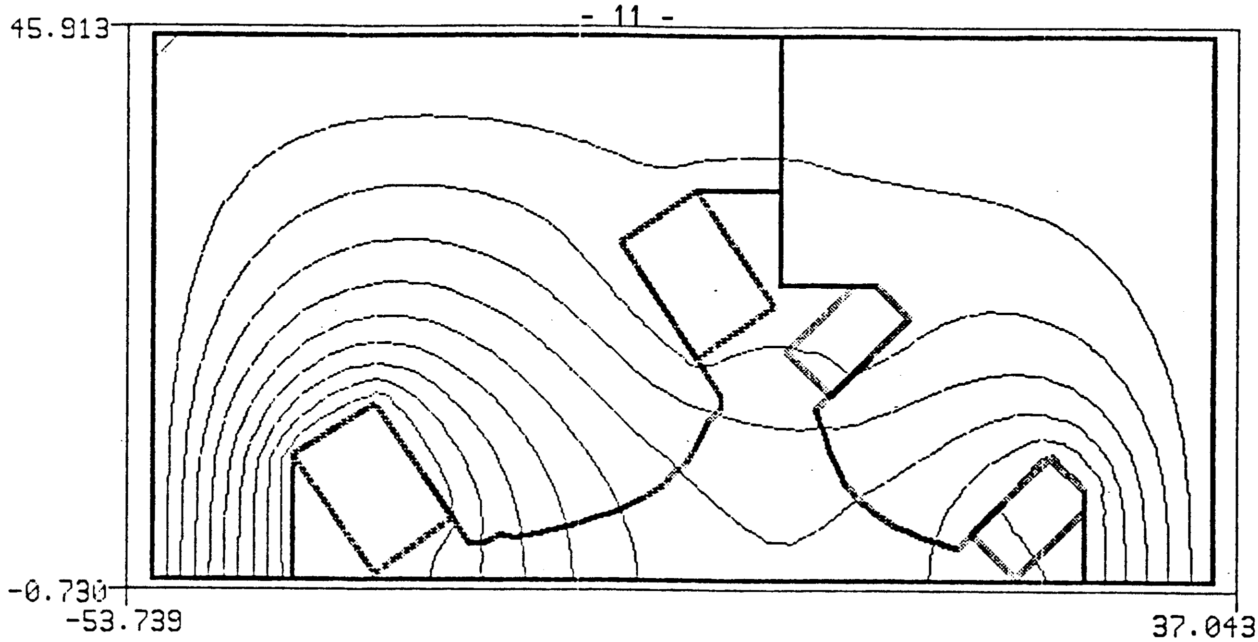
	QW		QN		
Number	20		36		
Gradient (D)	6.08	T/m	6.08	T/m	
Gradient (F1)			5.81	T/m	
Gradient (F2)	7.02	T/m			
Eff. length	700	mm	700	mm	
Core length	608	mm	618	mm	
Inscribed circle radius	132	mm	98.39	mm	
Overall length	810	mm	880	mm	
Overall width	1 600	mm	760	mm	
Good field width	± 174	mm	± 82	mm	
Good field height	± 63	mm	± 63	mm	
Nominal current (D)	1 640	A	1 640	A	
Nominal current (F)	1 893	A	1 568	A	
Nominal current (F_{TRIM})	325	A			
Nominal power (D)	47.8	kW	19.7	kW	
Nominal power (F)	63.8	kW	18	kW	
Turns/pole	27		15		
Conductor cross-section	20 x 17.3	mm^2	20 x 17.3	mm^2	
Current density (F)	6.4	A/mm^2	5.3	A/mm^2	
Coolant hole diameter	8	mm	8	mm	
Average length/turn	2.7	m	2.0	m	
Temp rise per coil (D)	20	°C	10	°C	2 coils in
Pressure drop per coil	9.6	bar	2.8	bar	serie for QN
Temp rise per coil (F)	27	°C			
Water flow per coil	8.5	l/mn	7.05	l/mn	
Water flow per quadrupole	34.1	l/mn	14.1	l/mn	
Resistance per quadrupole	17.7	mΩ	7.3	mΩ	
Copper weight	0.76	tonne	.315	tonne	
Steel weight	5	tonnes	1.66	tonne	
Total power	1.830	MW			
Total water flow	71.4	m^3/h			

SPECIAL MAGNETS

Due to injection constraints, one special dipole and two special quadrupoles will be required.

- For the dipole, the possibility to pass the beam through the iron and between the coils has been considered. However, it seems very difficult to retain this solution, because of large field variations between the coils. The possibility of builing a C magnet (septum magnet type) will be studied.
- For the quadrupoles, a very narrow one is needed (overall width $\sim$ 60 cm). Another half narrow and half wide is also needed. The design has been started and figure 5 shows some results.

A possible solution would be to build one special type with only 2 poles and find an appropriate way to close them for the flux.



field point table

x	y	potential	gradx	grady
-25.000	0.000	-234527.300	8519.280	177.437
-23.000	0.000	-217588.300	8153.388	250.545
-21.000	0.000	-201413.800	7637.001	344.710
-19.000	0.000	-186309.800	6926.479	362.620
-17.000	0.000	-172623.800	6179.148	378.417
-15.000	0.000	-160426.840	5399.356	376.341
-13.000	0.000	-160426.840	5399.356	376.341
-11.000	0.000	-160426.840	5399.356	376.341
-9.000	0.000	-133063.590	3097.603	367.711
-7.000	0.000	-126975.920	2339.668	366.791
-5.000	0.000	-122391.520	1583.722	367.623
-3.000	0.000	-119306.910	826.004	369.405
-1.000	0.000	-117725.700	64.609	371.263
1.000	0.000	-117655.210	-700.695	372.455
3.000	0.000	-119103.020	-1468.379	372.424
5.000	0.000	-122073.680	-2235.954	370.265
7.000	0.000	-126566.910	-2999.014	352.331
9.000	0.000	-132573.330	-3725.021	319.931
11.000	0.000	-140023.350	-3725.021	319.931
13.000	0.000	-148789.090	-4384.366	48.750
15.000	0.000	-157756.630	-4484.812	-425.154

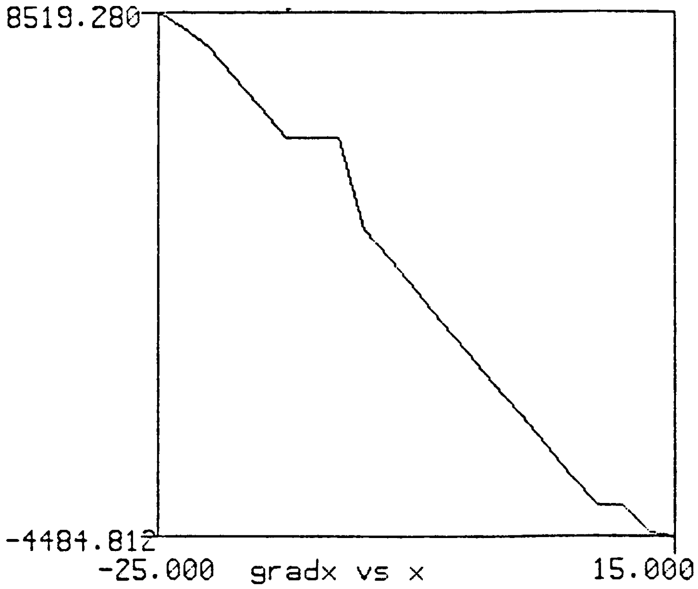


Fig. 5 : Magnetic field in the special quadrupole QDS 53

POWER DISSIPATION

Table 3 below gives the details.

	Number	Nominal power (kW)	Total
Dipoles	24	71	1 704
Quadrupoles $(D)_W$	8	47.8	382.4
Quadrupoles $(D)_N$	20	19.7	394
Quadrupoles $(F)_W$	12	63.8	765.6
Quadrupoles $(F)_N$	16	18	288
TOTAL...........			3 534.0 kW

TABLE 3

The total power dissipation is 3.5 MW.

POWER SUPPLIES

Four power supplies (and maybe six) will be necessary for the ring magnets. Table 4 gives this list with the corresponding parameters.

The requested precision is $\frac{\Delta I}{I} = 10^{-4}$

	Current (A)	Voltage (V)	Power (kW)
Dipoles (BHZ)	1 838	927	1 704
Quadrupoles (QDE)	1 640	474	776.4
Quadrupoles (QFO)	1 568	589	923
Trim quadr. (QFT)	325	405	131.6
Sextupoles (SDE)	-	-	-
Sextupoles (SFO)	-	-	-

TABLE 4

Further power supplies are envisaged for the special magnets and for the injection/ejection systems.

WATER COOLING

Dipole : Temperature rise per layer is 20°C ; then the water flow per layer is 3.7 l/mn, and the ΔP = 2.6 bars. By connecting 2 layers on the same circuit, we obtain a ΔP = 5.2 bars for each.

Quadrupoles : For the D wide, with a $\Delta\theta$ = 20°C per coil, we obtain a water flow d = 8.5 l/mn.
For the F wide, with an identical water flow, the temperature rise is 27°C. Each wide quadrupole can be cooled with a ΔP = 9.6 bars.
For the D and F narrow, we can connect 2 coils in serie in order to have $\Delta\theta$ = 20°C and then d = 7 l/mn with a ΔP = 5.6 bars.

Total water cooling :

Dipole	72.6	m^3/h
Quadrupole	71.4	m^3/h
	144.0	m^3/h

AVAILABLE SPACE BETWEEN MAGNETS

The Annexe 3 shows the available free space between 6 different magnet patterns. On the scheme 3, 4, 5, the sextupole magnets are not drawn at the place where it is intended to put them.

CONCLUSION

Detailed magnet specifications are being written.

All three-dimensional calculations will be started soon, this in order to optimize the pole profiles and to evaluate the shimming problems.

A good solution for the injection/ejection problems requires great care in the design of the special magnets.

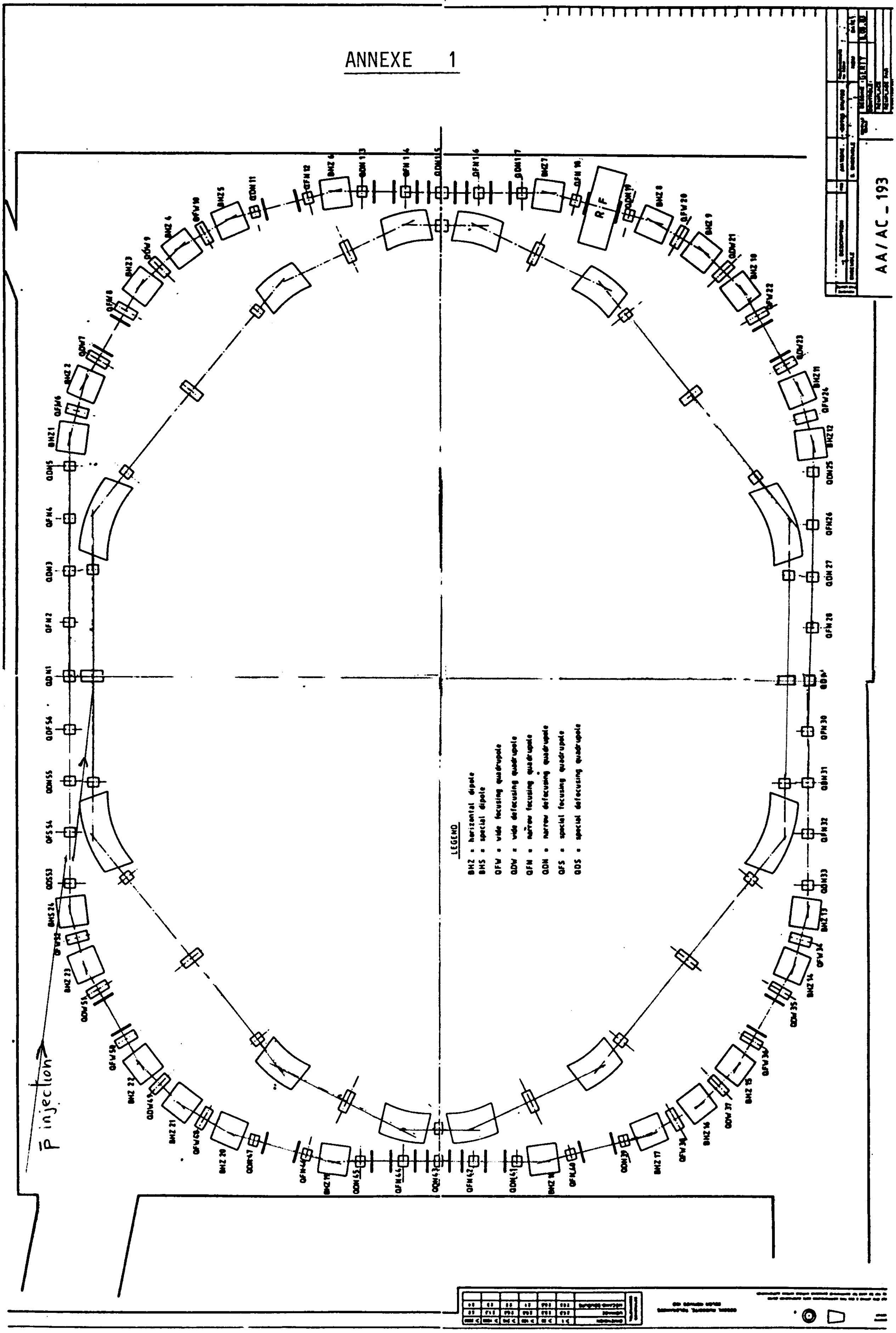
At the time of writing, 2 variations of lattice 83.08 have been considered :

- One is 83.08.D (W. Hardt) which allows more space in the straight sections and with a good symmetry for the dispersion function but it requires 6 different strength families for quadrupoles.
- Another is 83.08.S (R. Sherwood) which solves the $\overline{p}$ injection problems but it requires 8 special semi-quadrupoles (wide type). In this case the symmetry of the machine is respected with a different equilibrium orbit.

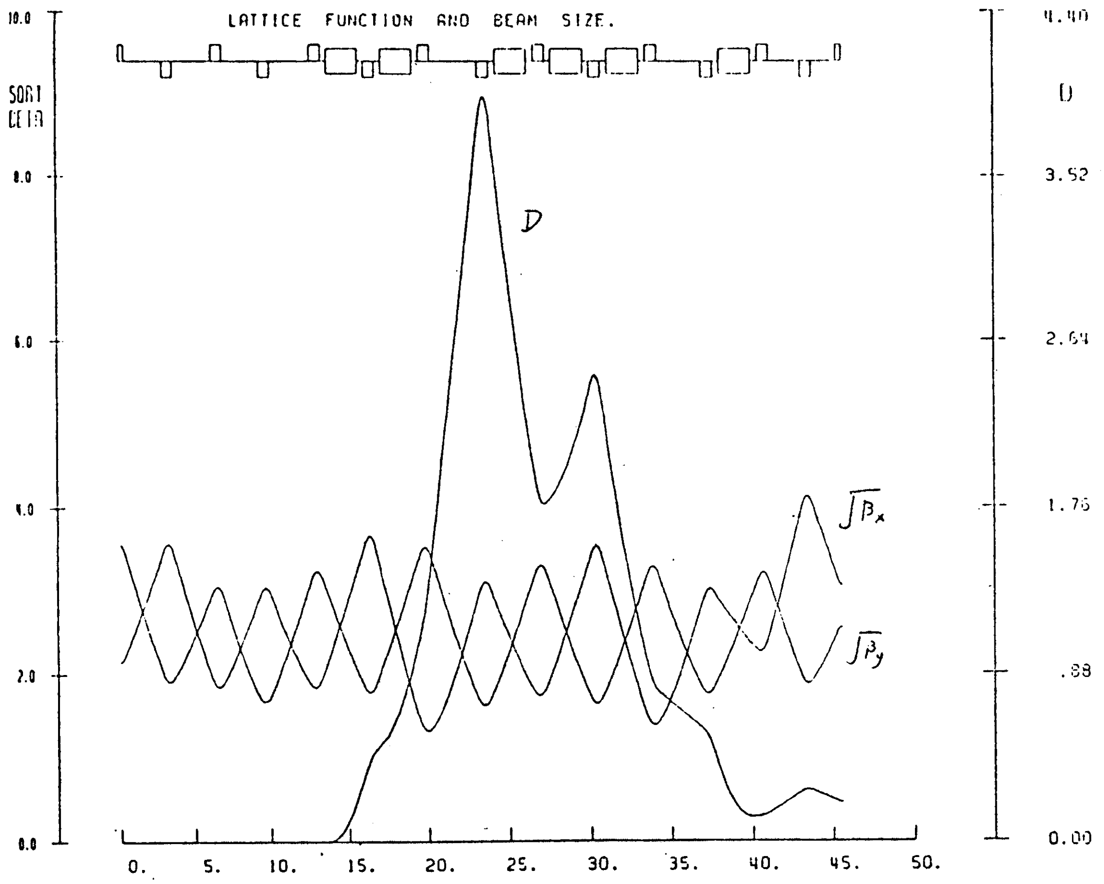
Both have not been studied in this note.

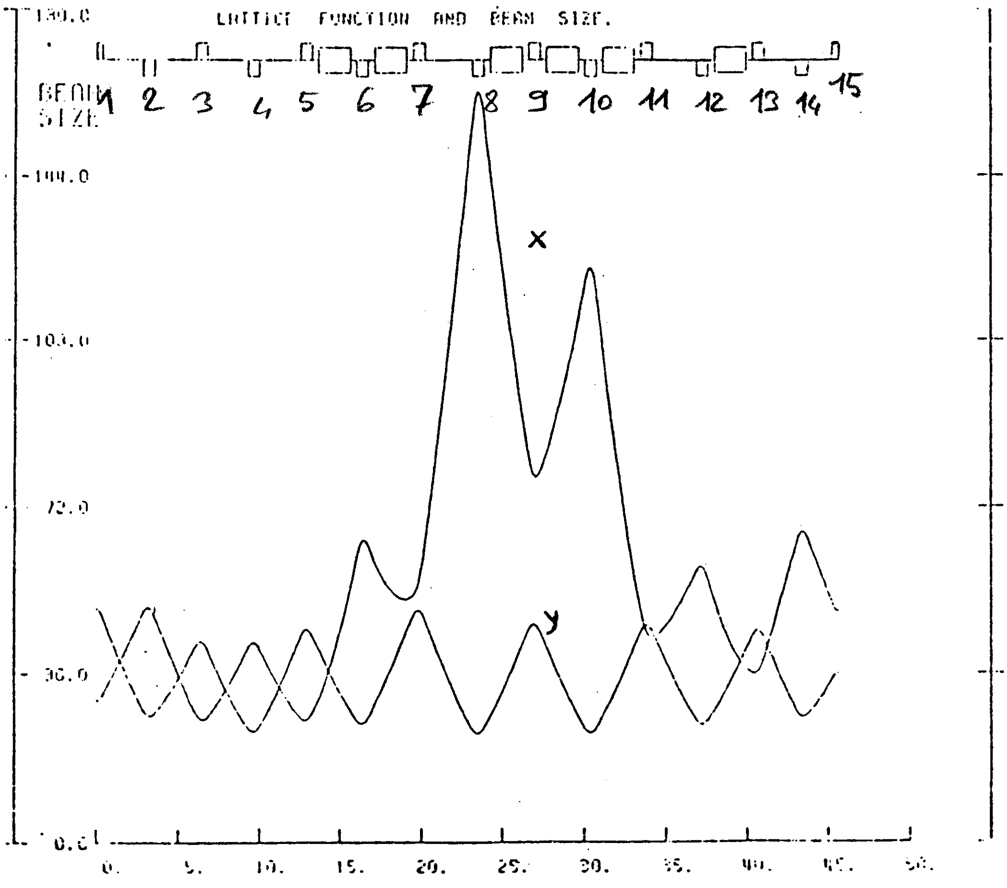
A large support has been provided by M. Harold (RAL) for this note and by W. Trowbridge (RAL) for the special quadrupole.

ANNEXE 1

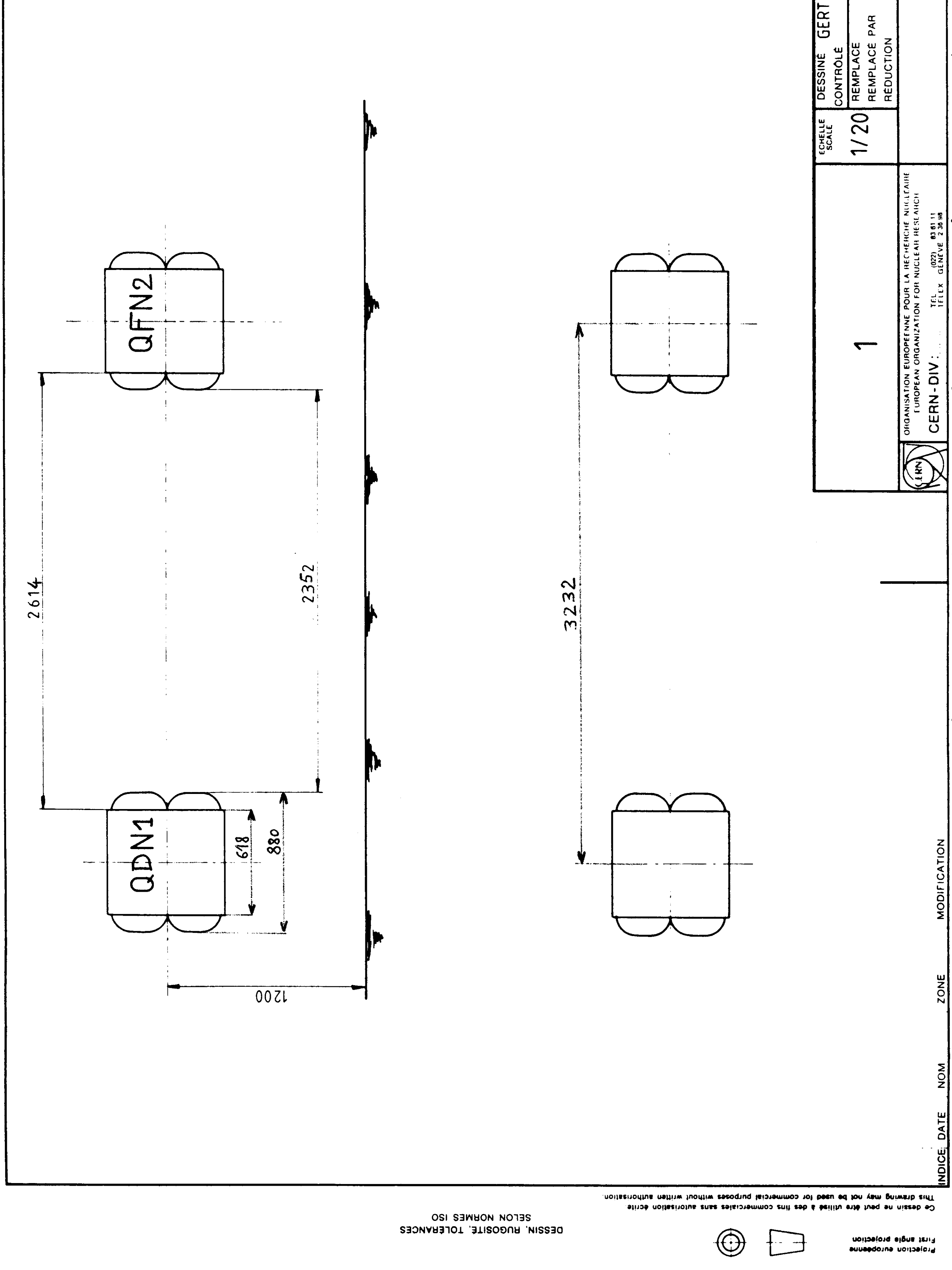

AA/AC _ 193
LEGEND
BHZ = horizontal dipole
BHS = special dipole
QFW = wide focusing quadrupole
QDW = wide defocusing quadrupole
QFN = narrow focusing quadrupole
QDN = narrow defocusing quadrupole
QFS = special focusing quadrupole
QDS = special defocusing quadrupole
R/F
p̄ injection

ANNEXE 2


LATTICE FUNCTION AND BEAM SIZE.
10.0
8.0
6.0
4.0
2.0
0.0
D
3.52
2.64
1.76
.88
0.00
D
√βx
√βy
0.
5.
10.
15.
20.
25.
30.
35.
40.
45.
50.


LATTICE FUNCTION AND BEAM SIZE.
BEAM SIZE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
x
y
0.
5.
10.
15.
20.
25.
30.
35.
40.
45.
50.

ANNEXE 3


QFN2
QDN1
2614
2352
3232
618
880
1200
DESSINÉ GERTY 9_08_83
CONTRÔLÉ
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REMPLACE PAR
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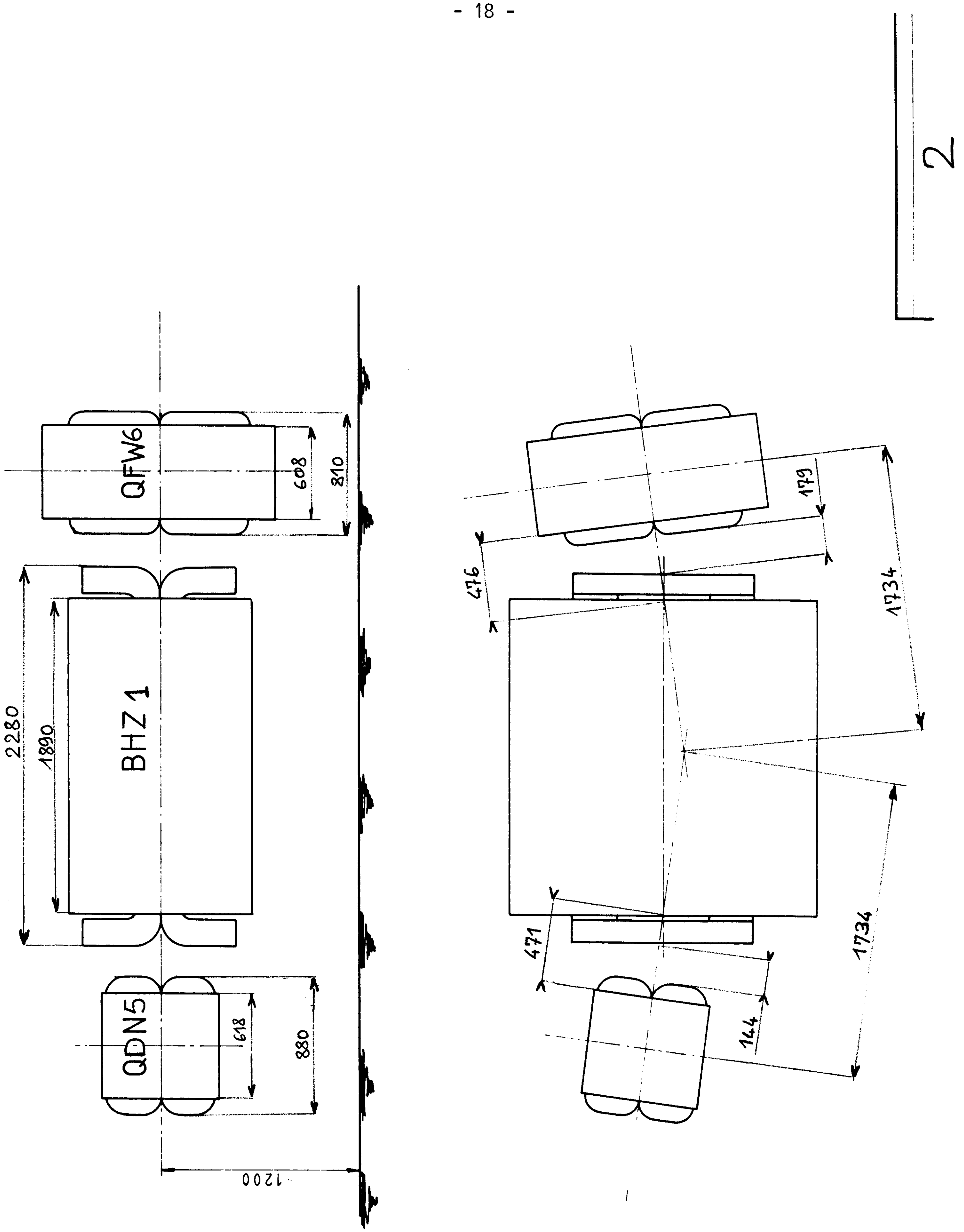
Projection européenne
First angle projection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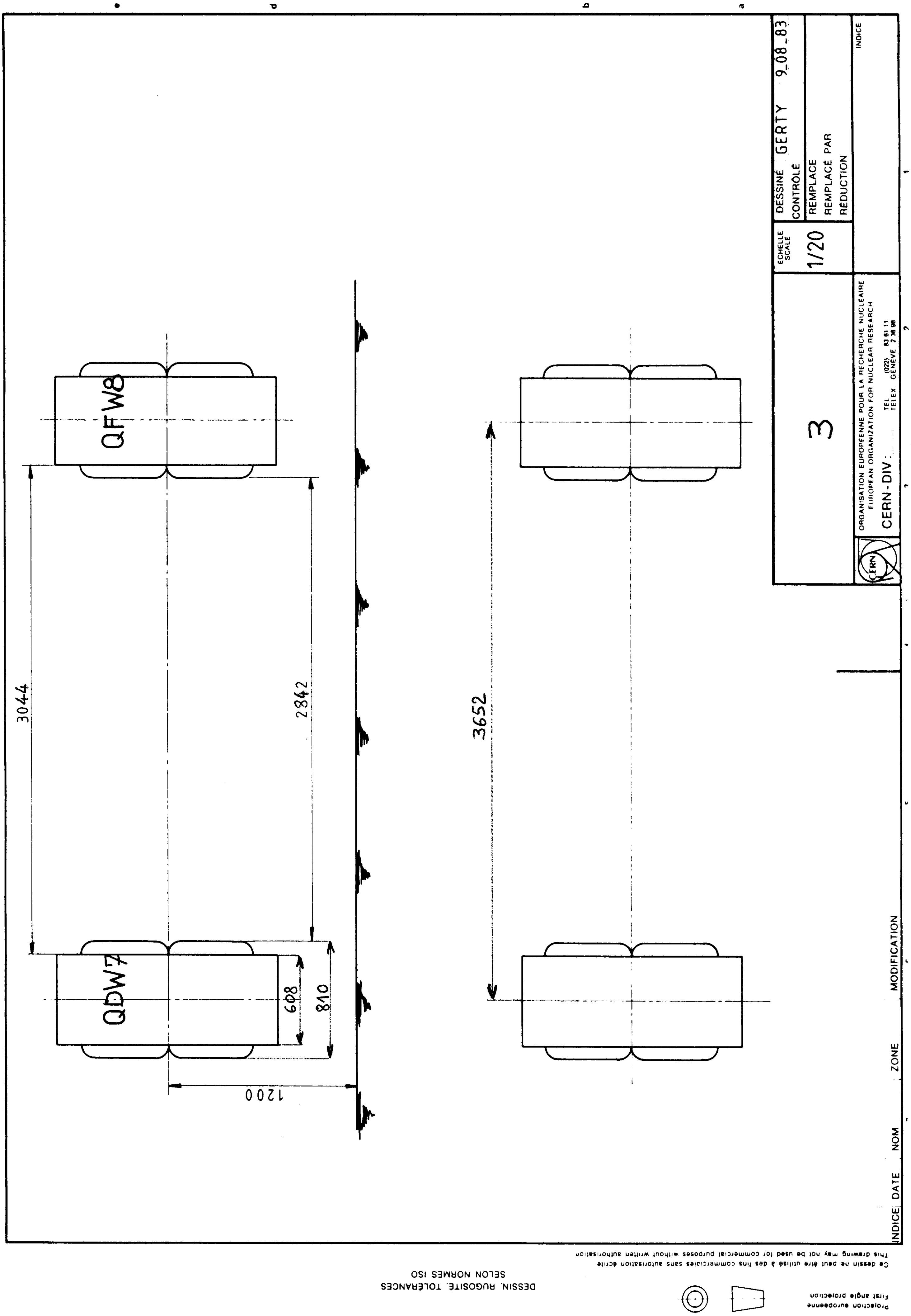
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RÉDUCTION
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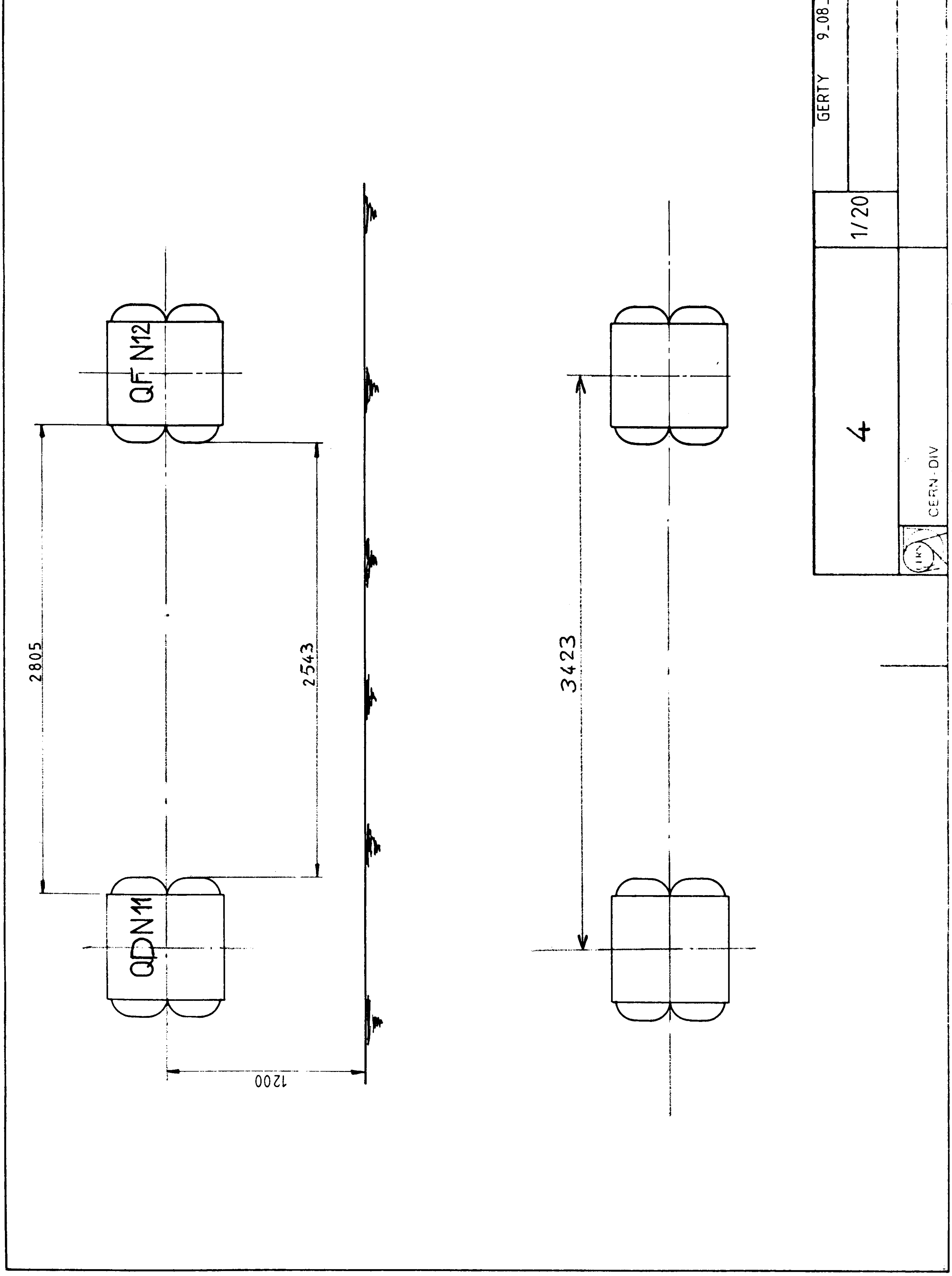
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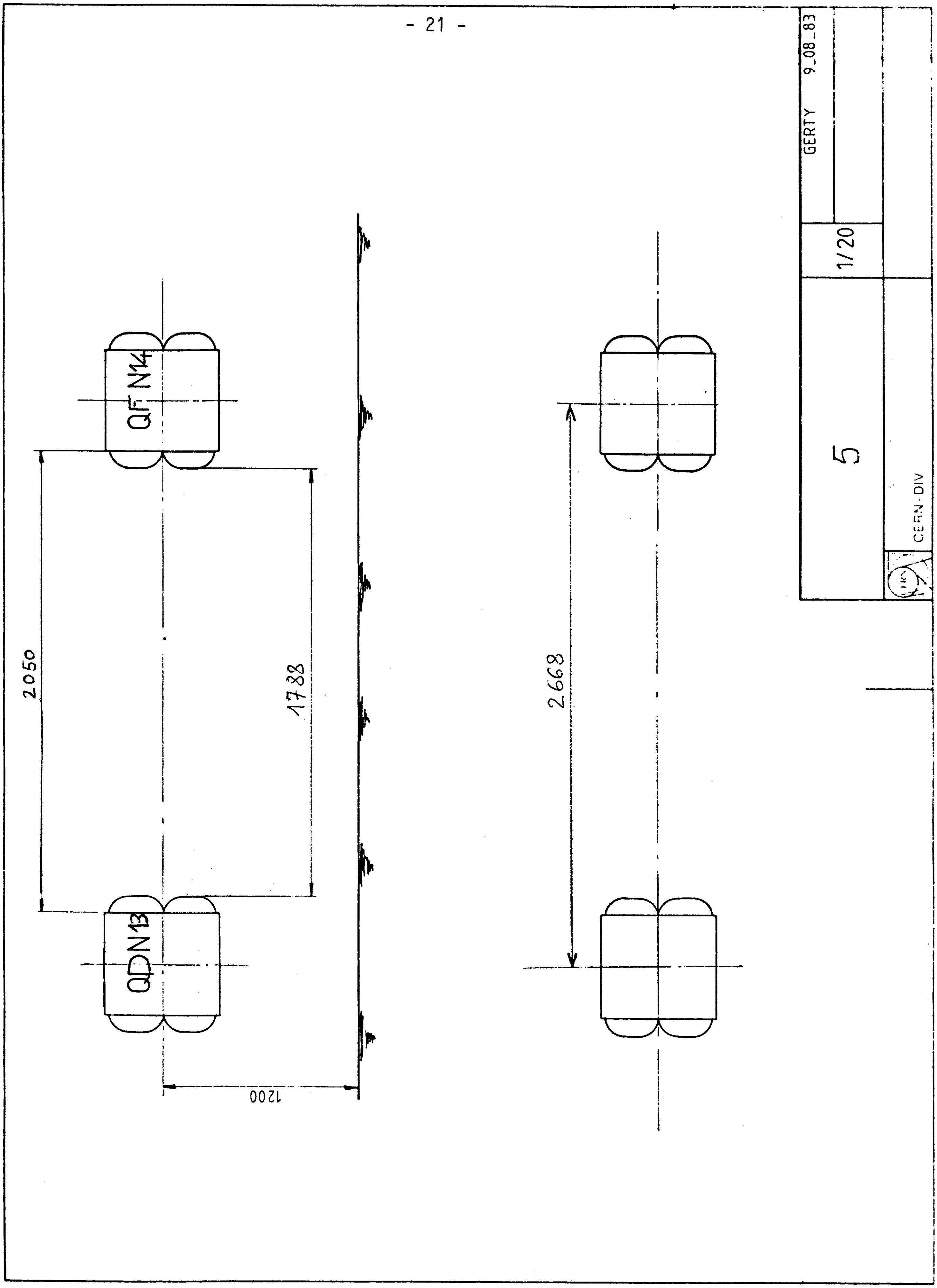
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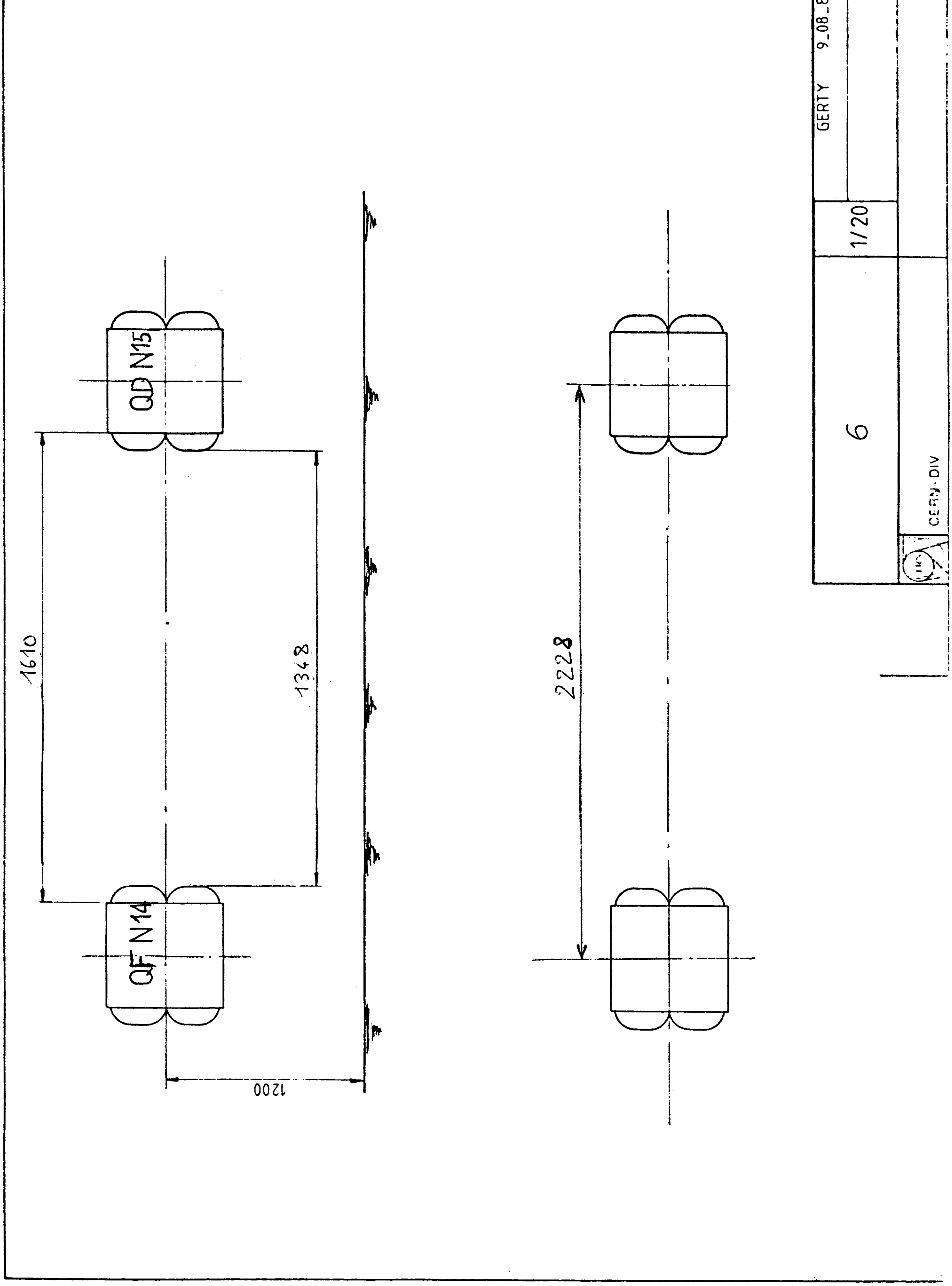
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