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RHIC Lattice

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U.S. Department of Energy
USDOE Office of Science (SC)

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RHIC-PG-33

RHIC LATTICE

J. Claus

(BNL, February 22, 1984)

Lattices for RHIC

Claus
Dell
Hahn
Ruggiero

Basic Facts.

Luminosity deteriorates as function of time due to intra beam scattering
↓
Luminosity life time
Time average luminosity

Life time and time average are limited by the ring admittances.

Problem: How to provide adequate admittance for acceptable cost?

Admittance is determined by aperture and focussing structure.
Transverse focussing structure consists of arcs and insertions.
Focussing in arcs determined by cell length and betatron phase advance/cell.
Cell length and phase advance affect the lattice functions, the intra beam scattering process and the cost differently.

Therefore: study different lattices.

How do we choose bench mark designs?
Different numbers of cells/arc: 9, 12, 15
Different phase advances/cell: 90°, 120°

Important constraint: γ_{tr}, a parameter set by the focussing structure.
The particle motion is subject to $\eta = \frac{1}{\gamma_{tr}^2} - \frac{1}{\gamma^2}$
$\gamma = E/E_0$.
$\eta = 0$ represents singular point, to be avoided or at least to be passed through quickly.
Cannot avoid it:

$\gamma_{tr} < \gamma_{inj}$ (~ 12.5/AMU) $\rightarrow$ impractically weak focussing

$\gamma_{tr} > \gamma_{final}$ (~ 100/AMU) $\rightarrow$ impractically strong focussing

However: proton injection at $\gamma = 31.4 \rightarrow$
$\gamma_{tr} \neq 31.4$

Options and Constraints.

1| Structure has to fit inside existing CBA tunnels

2| Injection must occur via existing beam transfer tunnels

3| Beams close together radially to allow use of 2 in 1 magnet designs or at least of common vacuum vessels

4| Dipoles of different rings on common radii for same reason

5| Side by side configuration (as in CBA) Over/under leads to more complex insertions.

6| $\beta_y^* = 3\,m$
$\beta_x^* = 3\,m$ (for $\alpha = 0$)
$x_p^* = 0.\,m$

7| Variable crossing angle ($0 \leq \alpha \leq 8$ mrad)

8| Adjustable betatron frequencies

9| Insertions decoupled from each other and from arcs.

1, 2, 8 Essential
6 Somewhat negotiable
9 Very desirable

1, 2, 6, 9 together pose a very difficult design problem.

Results so far

		# cells	phase advance
Def.:	RHIC1	9	90°
	RHIC2	9	110°
	RHIC3	12	90°
	RHIC4	15	120°

RHIC1,2 is a further development of the feasibility study lattice:

CBA → feasibility study → RHIC1 → RHIC2

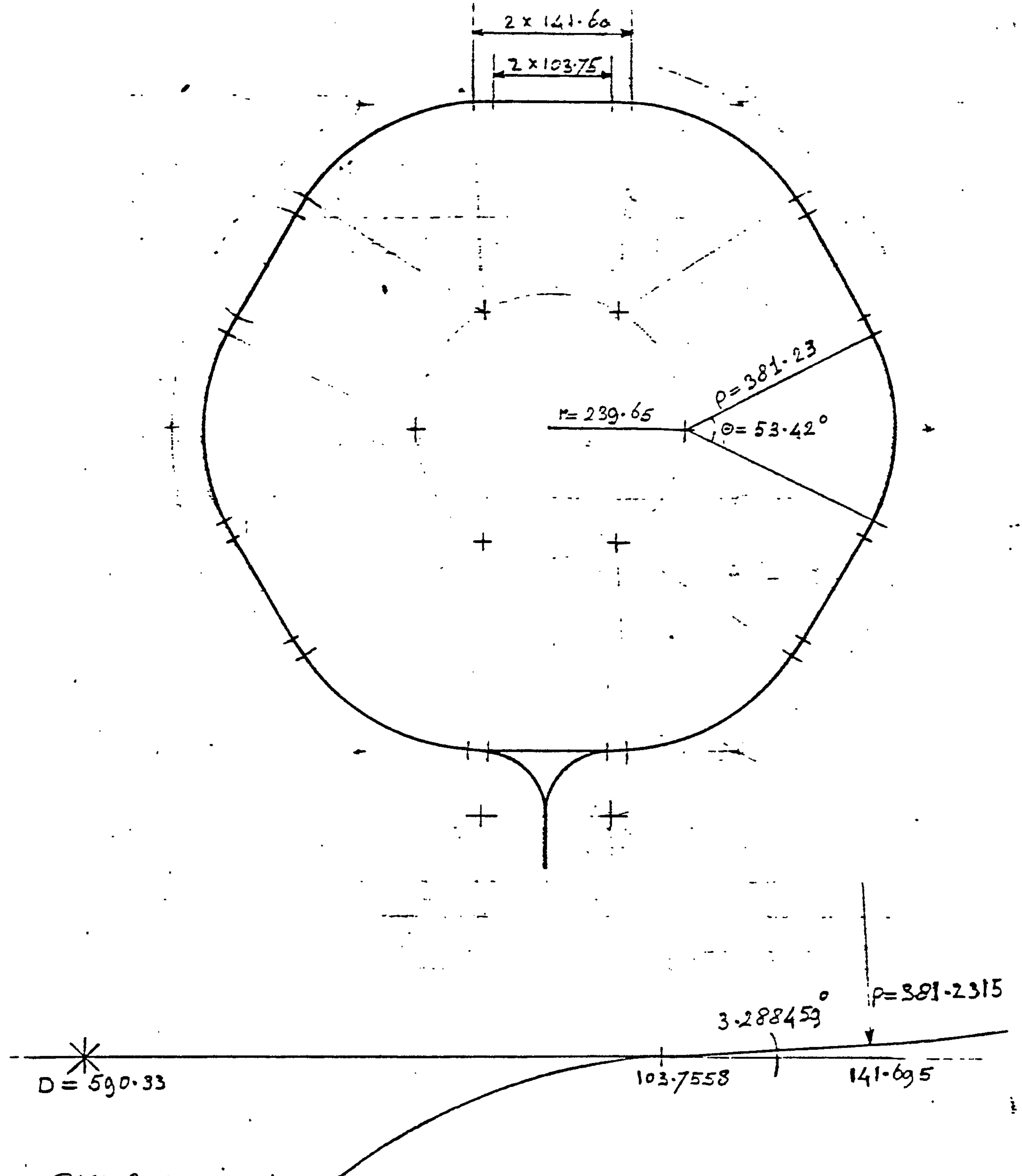
The aperture requirements decrease with increasing cell number, the component count increases with increasing cell number.

Status: RHIC1, RHIC3 (3 versions) ready for further work
RHIC2 (2 versions) needs minor touching up
RHIC4: in process.

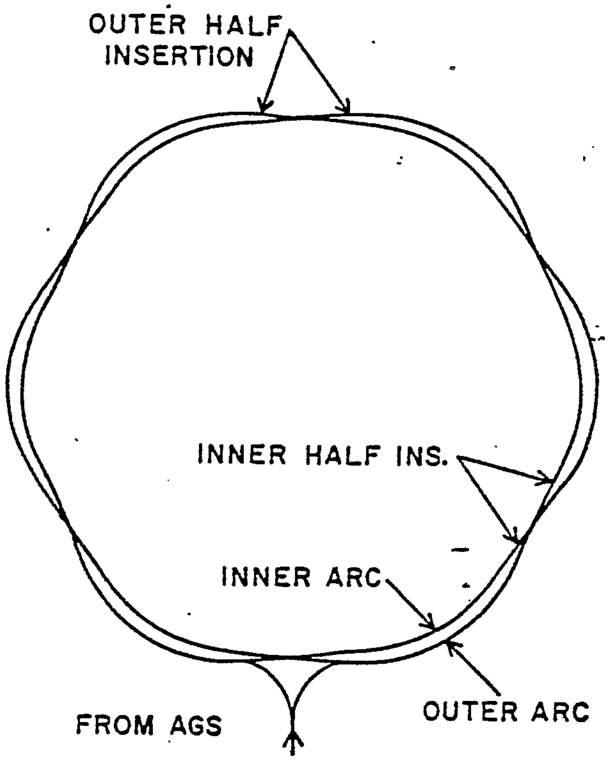
RHIC 2 B has a strongly asymmetric dipole distribution in the cells.
→ higher $\beta_h = 25.2$
inefficient use of available space
higher required dipole fields.

3 different insertions for RHIC3

		RHIC1	RHIC2		RHIC3			RHIC4
1	NAME	RHIC1	RHIC2			RHIC3		RHIC4
2	VERSION		A	B	A	B	C	
3	# Cells / Arc	9	9			12		15
4	Phase advance / cell	90	110			90		120
5	γ_{tr}	19	22.3	25.2		24.8		39
6	# dip	246	246			336		408
7	# quadrupoles	348	396		468	444	468	540/636
8	β_x^* / β_y^* (m)	40/2.0	2.7/2.9	2.7/3.0	17.1/30	22.4/3.0	29/3.0	?/?
9	$\hat{\beta} / \check{\beta}$ (m)	66.8/11.6	76/76	76/76		50/8.8		49.7/3.8
10	$\hat{X}_p / \check{X}_p$ (m)	2.7/1.3	2.1/0.9	2.0/0.75		1.5/0.75		0.7/0.29
11	$\Delta\psi_x / \Delta\psi_y$	1.5/1.5	2/2		1.5/1.5	1.5/1.5	2.0/2.0	
12	$\hat{\beta}_x / \hat{\beta}_y$ (m)	147/452	836/531		254/523	236/739	229/312	
13	ξ_x / ξ_y	-33/-52	-98/-75		-42/-53	-38/-65	-48/-56	-69/-69
14	$B''\ell / B\rho$ $(m)^{-2}$	0.0157/0.078	0.076/0.145		0.059/0.142	0.054/0.169	0.066/0.151	0.145/0.355
15	$B'\ell / B\rho$ $(m)^{-1}$	0.0358	0.0414			0.0477		0.0731
16	Half cell length (m)	19.75	19.75			14.81		11.85

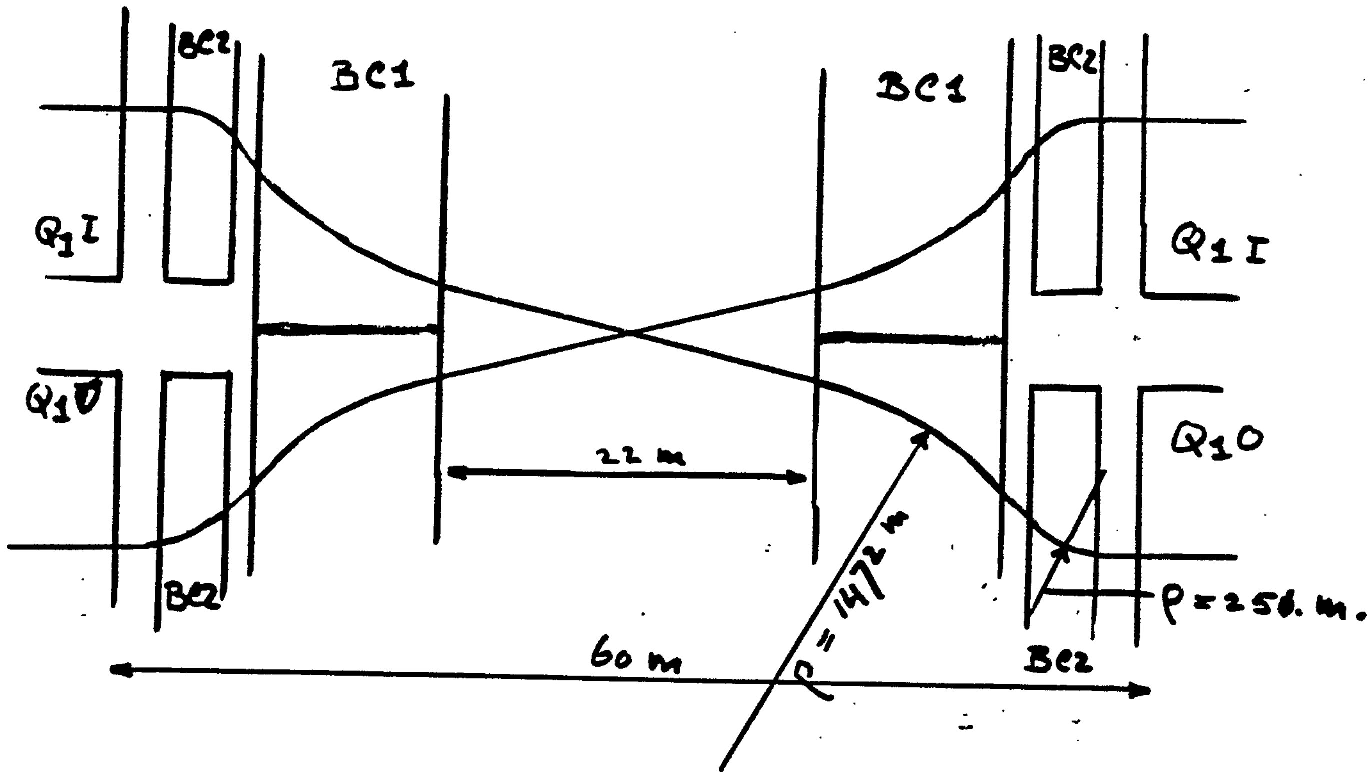


RHIC Tunnel
~~ISA~~ Geometry, July '78
circumference 3833.84 m

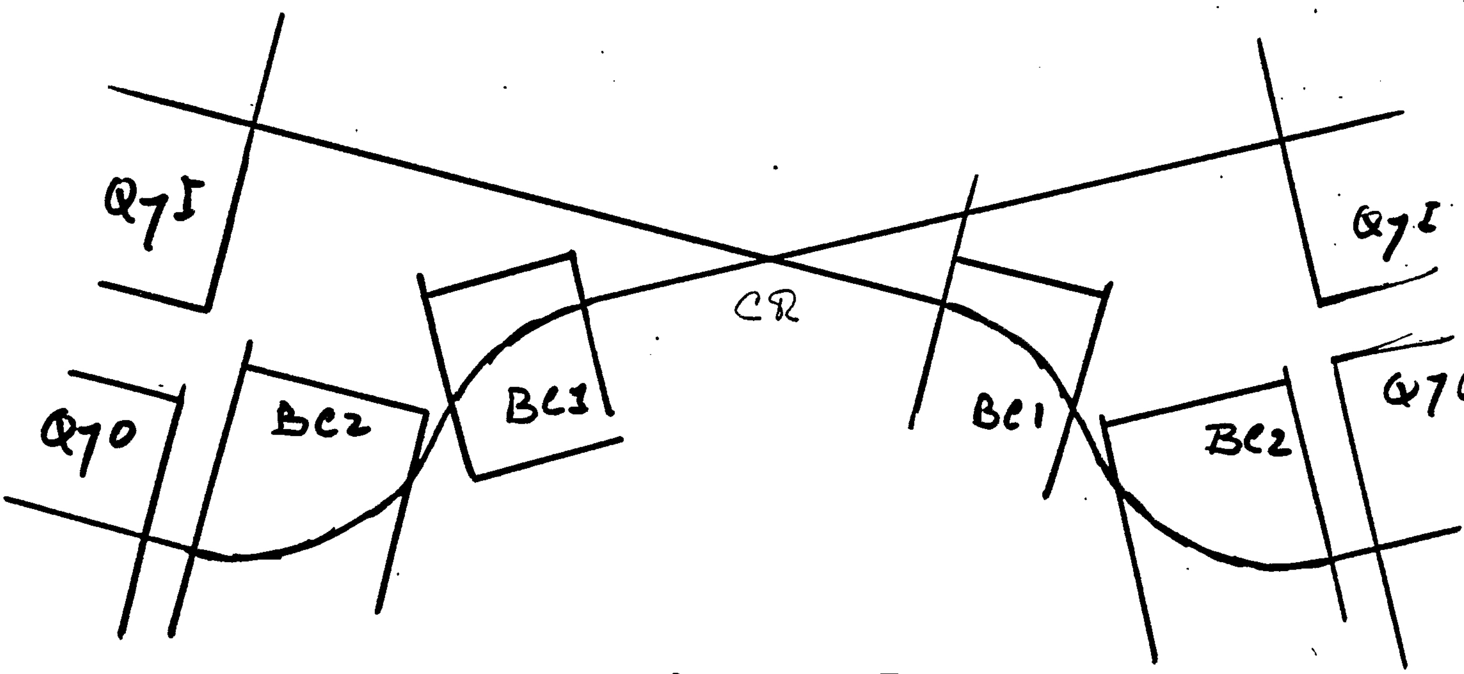


RHIC

Fig. 1.1. Topology of ~~ISABELLE.~~



Crossing point Configuration for RHIC.



Alternate Crossing Point Configuration for RHIC

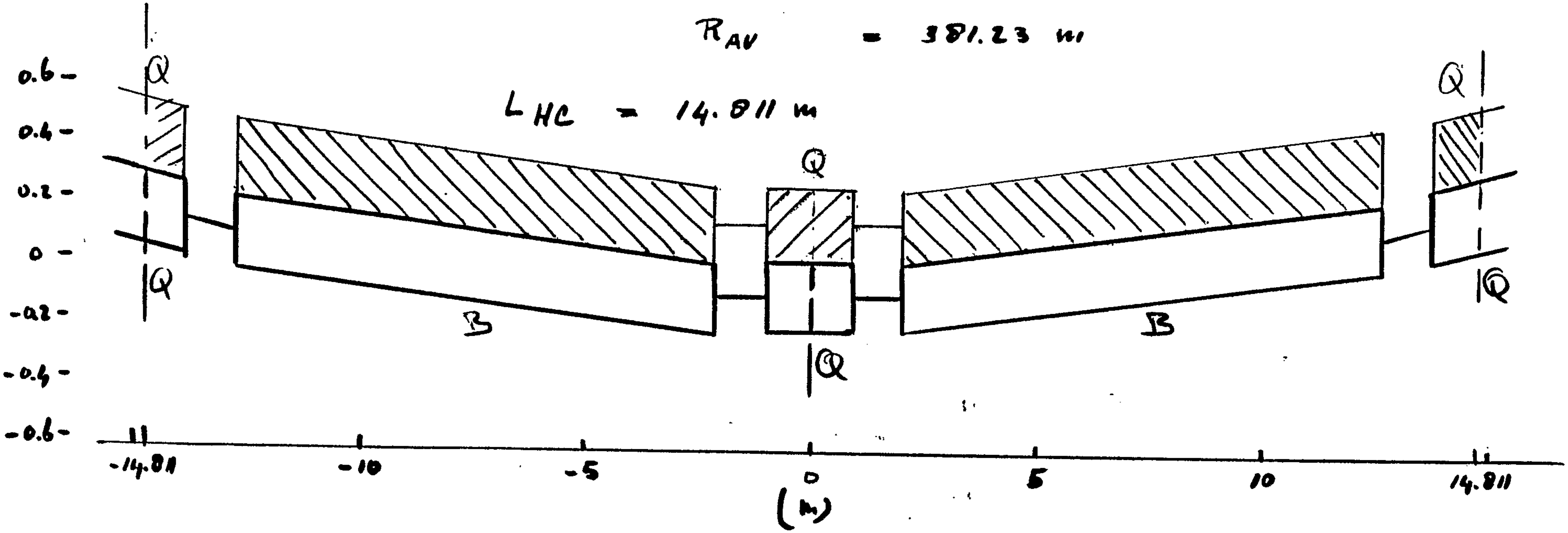
RHIC Regular Cell Pair (02/14/84 09.48.54)

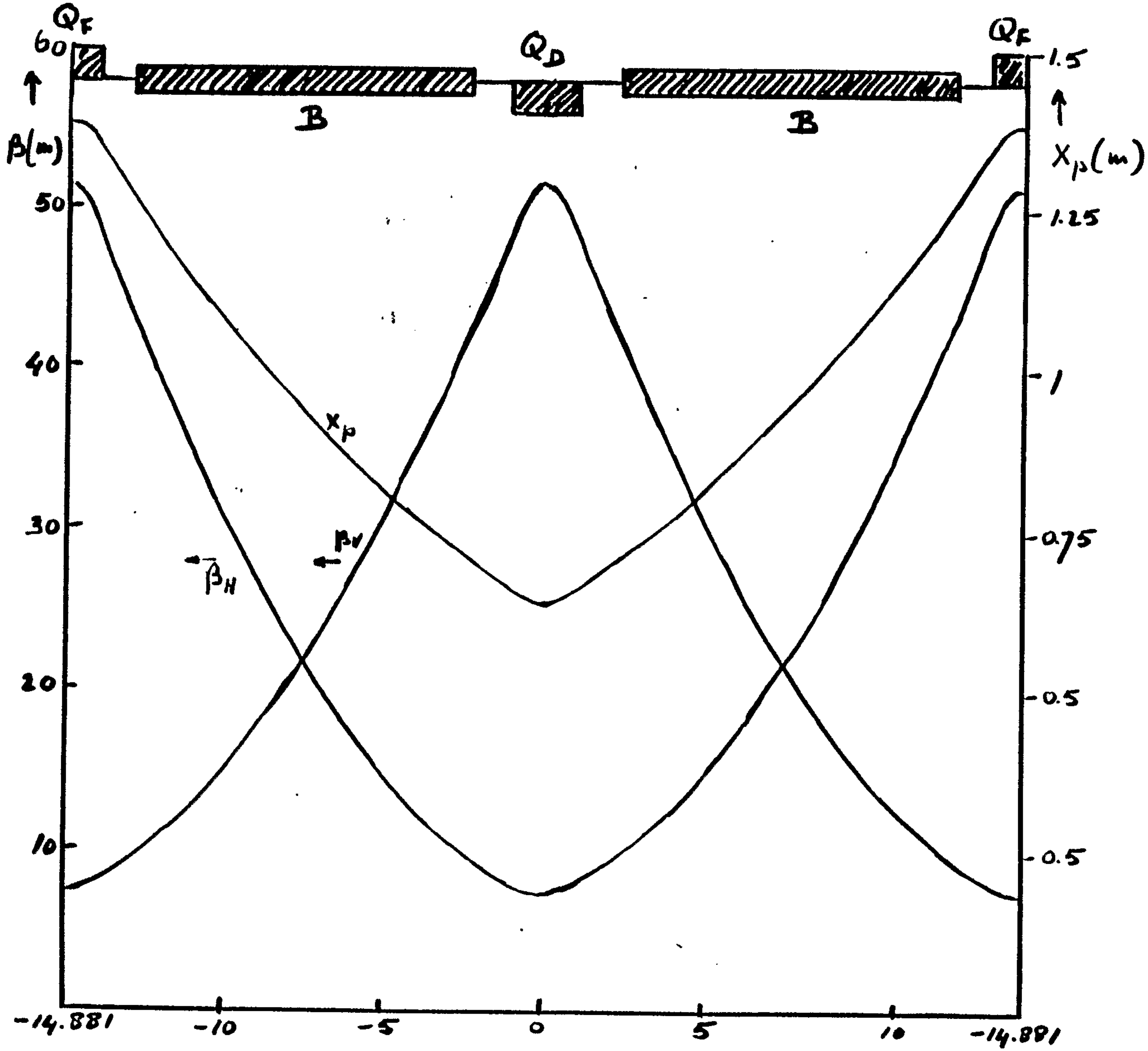
$$\Theta_{HC} = \frac{B_{dip}\, \ell_{dip}}{(B\rho)} = 0.03885 \text{ rad}$$

$$\frac{B'\, \ell_q}{(B\rho)} = 0.1066 \text{ m}^{-1}$$

$$R_{AV} = 381.23 \text{ m}$$

$$L_{HC} = 14.811 \text{ m}$$





RHIC REGULAR ARC CELL (02/14/84 09.48.54)

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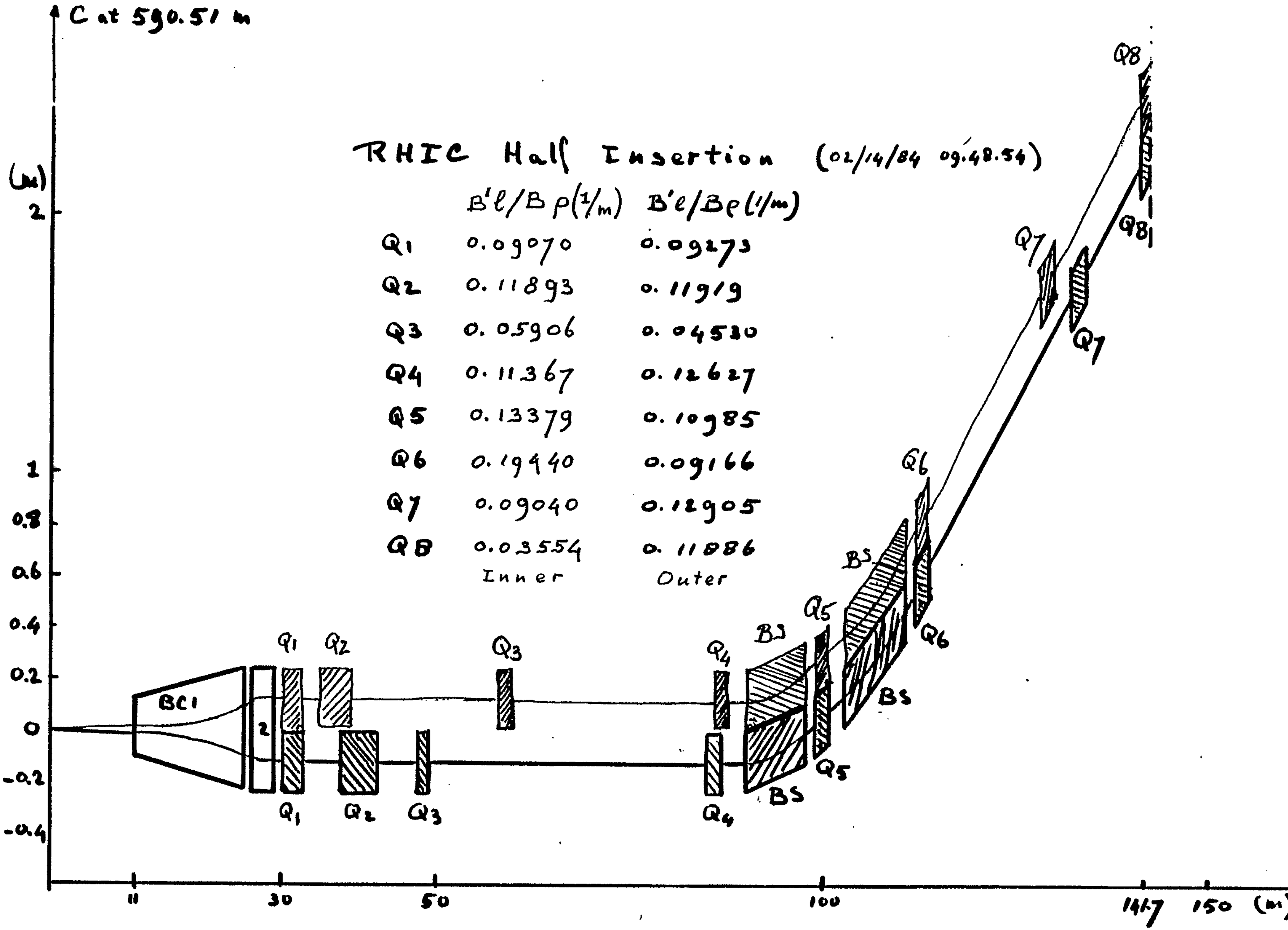
RHIC Half Insertion (02/14/84 09.48.54)

	$B'\ell/B\rho$ (1/m)	$B'\ell/B\rho$ (1/m)
Q1	0.09070	0.09273
Q2	0.11893	0.11919
Q3	0.05906	0.04530
Q4	0.11367	0.12627
Q5	0.13379	0.10985
Q6	0.19440	0.09166
Q7	0.09040	0.12905
Q8	0.03554	0.11886
	Inner	Outer



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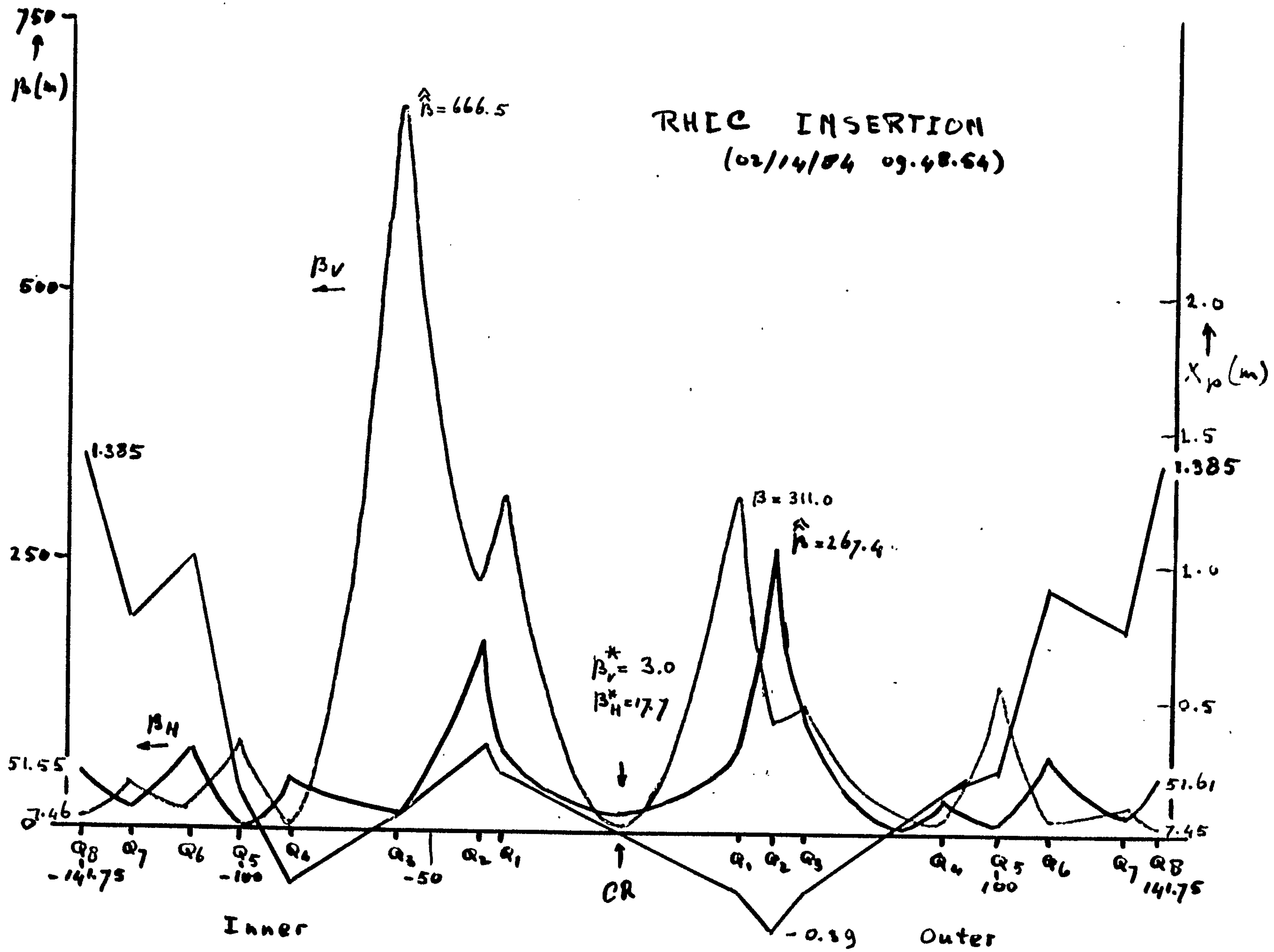


RHIC INSERTION
(02/14/84 09.48.54)
750
β(m)
500
250
51.55
7.46
0
1.385
βV
βH
$\hat{\beta}$ = 666.5
β = 311.0
$\hat{\beta}$ = 267.4
β_V^* = 3.0
β_H^* = 17.7
2.0
1.5
1.0
0.5
X_p (m)
1.385
51.61
7.45
-0.39
Q8 Q7 Q6 Q5 Q4 Q3 Q2 Q1
-141.75
-100
-50
CR
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8
100
141.75
Inner
Outer

RHIC LATTICE

General Parameters (02/14/84 09.48.54)

Circumference (m)	3833.845
Number of Sextants	6
Number of Insertions	6
Number of cells / Arc	12
Mean Radius of Arc (m)	381.23
Deflection angle / Arc (rad)	0.9324
Arc length (m)	355.46
Half cell length (m)	14.811
$\hat{\beta}_H$ / $\check{\beta}_H$ (m)	51.58/7.46
$\hat{\beta}_V$ / $\check{\beta}_V$ (m)	51.58/7.46
$\hat{x}_p$ / $\check{x}_p$ (m)	1.38/0.64
$\Delta\psi_H$ / $\Delta\psi_V$ (degrees)	100./100.
Insertion length (m)	283.509
β^*_H / β^*_V (m)	17.699/3.00
x^*_p (m)	0.
α^*_H / α^*_V	0/0.
$\hat{\hat{\beta}}_H$ / $\hat{\hat{\beta}}_V$ (m)	267.4/666.8
ν_H / ν_V	31.6/31.6
γ_{tr}	26.4

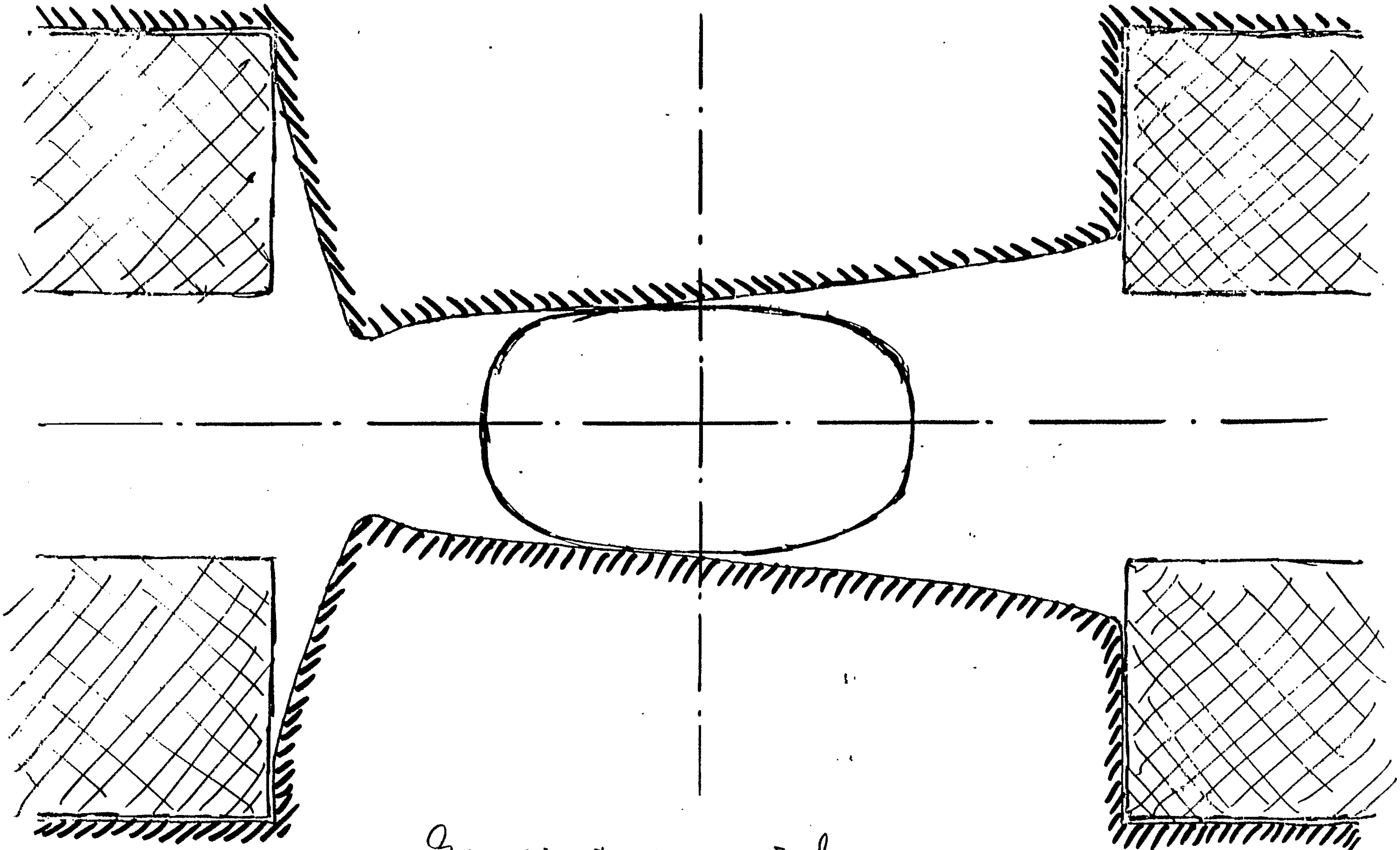
JCL 22 Feb '81.

Combined Function Lattices.

The table below gives the principal characteristics of four combined function lattices. Each has a deflection angle per arc of 60°, an average radius of curvature $R \lesssim 407$ m (this will still fit inside the CBA tunnel), and a betatron phase advance of 100°/cell. The focussing structure is FOFDOD, the driftspace O between magnets is 2 m long. We vary the number of cells, thus the magnetic bending radius ρ and the magnet length LM. We also adjust the $B\rho$ value, therefore the maximum energy per atomic mass unit such that the local gap field at 7 cm from the reference orbit is about 1.95 T, at 4 cm from the reference orbit it is never more than 1.875 T. The last line gives these characteristics for the "standard" RHIC 2 lattice.

# Cells	T (GeV/AMU)	R (m)	LHC (m)	ρ (m)	B (T)	B'/B (m)	LM (m)	$\Delta\psi$ (degrees)	$\hat{\beta}$ (m)	$\check{\beta}$ (m)	$\hat{X}_p$ (m)	$\check{X}_p$ (m)
12	73.5	406.6	17.74	360.7	1.70	3.68	15.74	100	53.89	9.53	1.70	0.89
13	70.7	406.7	16.38	357.3	1.65	4.35	14.38	100	49.57	8.82	1.45	0.76
14	67.8	407.0	15.22	353.5	1.60	5.06	13.22	100	45.87	8.22	1.25	0.65
15	65.0	406.8	14.20	349.5	1.55	5.85	12.20	100	42.63	7.69	1.08	0.57
12	100	381.2	14.81	275.4	3.03		10.7	100	51.58	7.45	1.39	0.64

JCL,
14 Feb '84



Gradient magnet for combined function RHIC.