Report on

THE DESIGN STUDY OF A 300 GeV PROTON SYNCHROTRON

by

The CERN Study Group on New Accelerators

Vol. II: Figures
(For Text see Vol. I)

day a good Are

GENEVA
Fig. II. 1  LAYOUT OF A NORMAL LATTICE PERIOD

Scale = 1 : 200

Fig. II. 2  LAYOUT OF A COLLINS INSERTION
FIG. 11-5 ELECTROSTATIC IMAGE FORCE COEFFICIENTS FOR A CYLINDER OF ELLIPTICAL CROSS SECTION

$E_\tau$ $\zeta_\tau$

$n = $ height

$w = $ width
FIG. III-1  LAYOUT OF A 30° MACHINE SECTOR
FIG.III-2 ONE OF THE 36 GROUPS OF MAGNETS AND LENSES
Equation of the ideal profile: \( y(17447 - x) + 9.66 \times 10^{-5}(3x^2y - y^3) = 6102.46 \text{ mm}^2 \)

**FIG. III - 3**

MAIN MAGNET F-SECTOR
TENTATIVE POLE PROFILE

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<th>y</th>
<th>x</th>
<th>y</th>
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<tr>
<td>20</td>
<td>31.38</td>
<td>140</td>
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straight line
arc of circle
straight line
ideal profile
equilibrium orbit
min gap

x (mm)

110
140

y (mm)

92.10
97.40
23.02
50
50
350

{}
FIG. III-4 MAGNET GAP AND VACUUM CHAMBER
FIG III-5 MAGNETIC CHARACTERISTIC OF A TYPICAL STEEL SAMPLE

\[ H_c = 0.66 \text{ Oe} \]
\[ \mu_{100} = 615 \text{ \ Oe} \]
\[ \mu_{15000} = 1370 \text{ \ Oe} \]
\[ \mu_{20000} = 704 \text{ \ Oe} \]
FIG. III-6 CROSS SECTION AND PARTIAL TOP VIEW OF A MAGNET UNIT
FIG. III-7 ONE QUADRANT OF A COLLINS QUADRUPOLE
FIG. III-8 MAGNETIC FIELD IN THE MEDIAN PLANE OF A COLLINS QUADRUPOLE

B (TESLA)

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

0 4 8 12 16 20 24 28 32 36 40 44 48 cm

0.02 T

SCATTERED PROTON BEAM
MAGNET CURRENT

MAGNET POWER

MAGNET PULSE SHAPE

Fig. IV. 1
BASIC ARRANGEMENT OF POWER SUPPLY

Fig. IV 2
EFFECTIVE 24 PHASE RECTIFIER SYSTEM
PROPOSED SYSTEM FOR EFFECTIVE 24 PHASE RECTIFICATION

Fig. IV. 4
AUXILIARY RECTIFIER SET AND BY PASS CIRCUITS
FOR INJECTION FIELD

Fig. IV 6
CYCLIC SPEED DROP FOR CONSTANT MOTOR TORQUE CHARACTERISTIC

Fig. IV. 7
Fig. V 1  RF acceleration station
FIG. VII-1 KINETIC ENERGY VERSUS FIELD IN LARGE PROTON SYNCHROTRONS
FIG. VII-2 STRAY REMANENT FIELD PATTERN IN STRAIGHT SECTION 72 OF THE CPS.
FIG. VII-3 SPACE CHARGE LIMITS IN THE MAIN RING AS A FUNCTION OF INJECTION ENERGY
Influence of systematic gradient errors on the working point in the booster. Fig. VII.4
\[
\frac{\Delta Q_h}{\Delta Q_{\nu}} = 100 \frac{\Delta \rho}{\rho} \left\{ \vec{a}_0 + \left( \frac{q}{n} \frac{dn}{dr} \right)_F \vec{a}_F + \left( \frac{q}{n} \frac{dn}{dr} \right)_D \vec{a}_D \right\}
\]

Influence of systematic sextupole-fields on the dependence of the working point on the momentum in the booster

Fig VII 5
Machine centre

Booster magnet

F-unit cross section

scale 1:10 — Fig VII.6
Machine centre

Booster magnet

D - unit cross section

scale 1:10 — Fig VII 7
girder

D - unit

F - unit

Booster magnet

top view of the units

scale = 1:25

Fig: VII 8
NORMAL VOLTAGE DISTRIBUTION AROUND RESONANT NETWORK

Fig. VII.10
WAVEFORMS OF RESONANT MAGNET NETWORK  FIG. VII.11
VOLTAGE AND CURRENT WAVEFORMS OF PULSE POWER SUPPLY.

FIG. VII.13
SERVO CONTROL SYSTEM FOR I_{ac}  Fig. VII.14
SERVO CONTROL SYSTEM FOR $I_{dc}$  

Fig. VII.15
Fig VII 16  Mechanically tuned RF cavity for booster
cross-section of the supporting ribs

D-unit

F-unit

frame for the foil

metal pipe

ceramic spacers (short cylindric tubes)

supporting ribs

r = bending radius

supporting ribs

thin foil

XX cross sections

The vacuum chamber of the booster. scale 1:25 - Fig VII 17
The gradient disturbance by eddy currents in the booster vacuum chamber wall. \( t=0.1 \text{mm}; \) \( \frac{1}{\alpha} = 10^{-6} \text{Ohm.m}; \) \( \frac{\dot{B}}{B_{\text{max}}} = 216/\text{s} \)
Fig. VII-19 INJECTION INTO THE BOOSTER
Fig VII.20  EJECTION TRAJECTORY IN THE BOOSTER
Fig. VII.21 INJECTION INTO THE MAIN RING
Fig. VII.22  EJECTED BEAM AT THE ENTRANCE OF THE SEPTUM MAGNET IN THE BOOSTER
DISPLACEMENT OF BOOSTER R.F. PHASE BY $+\pi$

Initial condition

First jump: $t=0$

Half a phase oscillation

Second jump: $t=T_p$

DISPLACEMENT OF BOOSTER R.F. PHASE BY $-\frac{\pi}{2}$

Initial condition

First jump: $t=0$

Second jump: $t=T_p$

Fig VII.23 BOOSTER PHASING BY PHASE-JUMP
Fig VII.24 Electronic system for phasing.
Fig VII.25  Zero beat indicator.

Fig VII.26  Phase splitter.
Fig VII.27 Nonlinearity of phase oscillation

Locus of particles which have started at $t=0$ from negative abscissa after:

- $a$: $t = T_{po}$
- $b$: $t = 1.07 T_{po}$
- $c$: $t = 1.12 T_{po}$
- $d$: $t = 1.18 T_{po}$
Fig VII.28 Bunch before (a) and after (b) phasing for $\varphi_0 = 180^\circ$
Fig VII.29 Bunch of ±40° original length before and after phasing, for \( \Phi_0 = 180° \)
### Parameters of Structure for a 200 MeV Linac

#### Unit Alvarez Cell

**Fig VII 30**
Fig. VII.31 EQUIVALENT CIRCUIT FOR A RESISTIVE SOURCE IMPEDANCE AT THE LOOP TERMINALS.

Fig. VII.32 RF PULSE POWER PROGRAMME
MOMENTUM JITTER v PHASE ERROR FOR VARIOUS VALUES OF FIELD ERROR

Fig. VII.33
Fig. VIII-1 ENERGY SPECTRUM OF PIONS OF ONE SIGN PER NUCLEON-NUCLEON INTERACTION AT 300 GeV AND AT VARIOUS ANGLES.
TRAJECTORIES OF POSITIVE PARTICLES PRODUCED IN T2

TRAJECTORIES OF SCATTERED PROTONS FROM T1

MAGNET LAYOUT NEAR COLLINS STRAIGHT SECTION.
BEAM ENVELOPE OF 2.5 mrad
SCATTERED PROTON BEAM.
TRAJECTORIES OF NEGATIVE SECONDARIES IN A BENDING MAGNET TRIPLET.
Fig. VIII. 7 PHASE PLANE DIAGRAM OF FORCED BETATRON OSCILLATIONS IN THE CENTRE OF EQ
Fig. VIII. 8  Envelope of slow ejected beam (AB) and trajectory C just grazing the septum of ESMf
FIG VIII. 9  TRANSVERSE MOMENTUM DISTRIBUTION OF SECONDARY PARTICLES
Fig. IX.1 MUON FLUX DENSITY AT VARIOUS DEPTHS IN THE SHIELDING
Fig. IX.2  Shielding for external target of a 300 GeV P.S.
Fig. XII 3 SKYSHINE FLUX AS FUNCTION OF DISTANCE FROM RING CENTRE
BUILD-UP OF INDUCED RADIO-ACTIVITY

(assuming constant intensity of irradiation)
DECAY OF INDUCED RADIO ACTIVITY AFTER CONSTANT IRRADIATION  Fig IX 5
DISPOSITION GENERALE DES AIMANTS

MISE EN PLACE DES PILIERS

MISE EN PLACE DES AIMANTS

Figure XI - 1

Figure XI - 2

Figure XI - 3
Figure XI-4. MISE EN PLACE DES PILIERS ET AIMANTS DU BOOSTER
CPS Mise en place des aimants

FIG. XI - 5
Erreurs moyennes quadratiques sur l'ensemble des mesures 0.04 mm.

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FIG. XII-1
Distance NORD-SUD 150 m. 00360

Distance EST. OUEST 129 m. 90760

Variation de longueur dans deux directions perpendiculaires MARSEILLE

FIG. XII-2
MARSEILLE

Répartition des différences entre les valeurs extrêmes des longueurs de 50 mètres

FIG. XII-3

27.26 distance mesurée entre les piliers 27 et 26
BOOSTER

TYPICAL CROSS SECTION

~ 218.00

1.20 ~ 174.0

5.40

4.00

1.25

1.70

~ 194.00

45

5.00

CENTRE DRAINAGE

10 Ton CRANE

BEAM AXIS

FIG. XIII–13
300 GeV PROTON SYNCHROTRON
GENERAL ARRANGEMENT OF POWER DISTRIBUTION

FIG. XIII-19
a) REVERSED-RETURN SYSTEM AS APPLIED TO THE MAIN MAGNET OF THE CERN PS

b) REVERSED-RETURN SYSTEM AS IT COULD BE ADAPTED TO THE MAIN MAGNET OF A 300 GeV MACHINE

c) PROPOSED ARRANGEMENT OF COOLING PLANTS AND DEMINERALIZED COOLING WATER DISTRIBUTION SYSTEM FOR MAIN MAGNET OF 300 GeV MACHINE

ASSUMED TERMINATION POINT OF RAW WATER SUPPLY LINE

12

1

2

COOLING PLANT FOR BOOSTER AND LINAC

COOLING PLANTS FOR MAIN MAGNET

COOLING PLANTS FOR RF SYSTEM

COOLING PLANTS FOR AIR CONDITIONING SYSTEM

C

D) LAYOUT OF COOLING SYSTEM COMPONENTS

CENTRAL COOLING PLANT SERVING ALL THE EXPERIMENTAL AREAS

DETAILS OF COOLING SYSTEM COMPONENTS
COOLING SYSTEMS WHICH HAVE BEEN STUDIED

- RAW WATER OR COOLED TOWER WATER
- RECOOLED AVERAGE REFRIGERANT OR DENITRIFIED WATER
- HEAT PUMP CIRCUIT
- HEAT EXCHANGER (WITH OR WITHOUT CHANGE OF PHASE)
- COOLING TOWER
- AIR TO WATER HEAT EXCHANGER OR AIR-COOLED CONDENSER
- PUMP
- REFRIGERANT COMPRESSOR
- REFRIGERANT EXPANSION DEVICE
- DRAIN

FIG. XIII - 22
OVERALL COST OF DIFFERENT COOLING SYSTEMS AS A FUNCTION
OF DISTANCE OF WATER SOURCE

NOTES: 1) OVERALL COSTS DO NOT INCLUDE INITIAL COST AND CAPITALIZED POWER COST OF COMPONENTS WHICH ARE
COMMON TO ALL THE SYSTEMS.
2) THE DISTANCE OF THE RAW WATER SOURCE IS MEASURED ALONG THE RAW WATER SUPPLY LINE DEPARTING FROM
A POINT BETWEEN COLLINS STRAIGHT SECTIONS 12 AND 1.