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THE BEAM TRAJECTORY AND THE SHIELDING OF THE MUON STORAGE RING EXPERIMENT

I. THE BEAM TRAJECTORY :

(based on information given in MSR/7 by F.J.M. Farley and private communication from S. van der Meer and M. Giesch). One aims to eject one proton bunch at 12 GeV/c along the existing fast ejection trajectory up to the bending magnet placed near straight section 3. The bending magnet (type 1060) deflects the beam away from the other neutrino beam transport elements. The beam enters magnet 1060 along its axis. Some characteristics and performances of magnet 1060 are :

effective length 1.10 m.
relation : current-magnetic field is shown on the attached graph.
at maximum current with generator type II (760 A) :
21.9 Wb/m^2, gives 60.2 mrad deflection for 12 GeV/c, protons.
maximum field about (950 A) : 23.9 Wb/m^2, gives 65.7 mrad deflection for 12.0 GeV/c protons.

No further deflection has been planned after the beam has passed magnet 1060.

The lower limit for the deflection inside the ring area is determined by the presence of B3, the horizontal bending manget of the fast ejection placed near magnet unit 3. (see drawing 28-1705-0). This lower limit corresponds to about 33 mrad deflection in magnet 1060.

The upper limit inside the ring area is set by the maximum field in 1060, resulting in about 66 mrad for 12 GeV/c protons. The trajectories corresponding to the upper and lower deflection limits are shown on the attached drawing.

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Maximum deflection is desirable seen the equipment lay-out of the neutrino bubble chamber. However the maximum deflection is interfering with the experimental zone of the d-beam. This interference is a minor one by omitting the shielding around the beam pipe inside the d-beam zone. The d-beam zone shielding can serve as shielding for the ejected beam as well. (see II)

Equation of proposed trajectory :

$$Y = 0.51675\ X - 14.09376$$

origin : X = 32.4700 Y = 2.6850 Being the centre of bending magnet 1060.

The trajectory is followed by 12.0 GeV/c protons deflected by 65.71 mrad in magnet 1060 (23.9 Wb/m^2, 950 A) or 11.0 GeV/c protons deflected in a field of 21.9 Wb/m^2 (760 A).

II. <u>SHIELDING OF THE BEAM PIPE IN THE SOUTH HALL</u> (a prelimary study to obtain an approximate size of shielding required).

The PS intensity is assumed to be 10^{12}P/P or about 2.5 10^{10}P/S ejected on the target inside the storage ring.

The beam size will be according v. der Meer's calculations :

horizontal half width at origin :	7.3 mm
" " " at first quadrupole :	60.0 mm

So the boundary ray makes an angle of .66 mrad with the beam axis.

vertical half width at origin :	9.0 mm
" " " at first quadrupole :	23.4 mm.

So the boundary ray makes an angle of .18 mrad with the beam axis.

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To reduce the consequences of a maladjusted ejected beam in the South Hall, two collimators in the ring area and one after the main shielding wall are proposed.

Proposed collimator dimensions and positions :

Coll. No. 1, 15m from origin, 1.2m long, steel.
hor. half width 20mm
vert. " " 15mm

Coll. No. 2, 20m from origin, 1.2 m. long, steel
hor. half width 30 mm
vert. " " 20 mm

Coll. No. 3, 30m from origin, 1.2 m long, steel
hor. half width 40 mm
vert. " " 20 mm

The horizontal boundary ray will touch collimator n° 1 when it has been deflected around the origin by 0.85 mrad.

The beam axis will touch collimator No. 1 when it has been deflected around the origin by 1.33 mrad. A 1.33 mrad deflected axis will deviate 106mm from the central beam axis at the first quadrupoles.

A proton scattered in the horizontal plane on the wall of collimator No. 1 under 2.6 mrad with the central beam axis will have a deviation of 150mm at the first quadrupole as a proton scattered under 4 mrad will still just pass collimator No. 3 without scattering and obtain a 150 mm deviation from the axis at 27.5 m from collimator No. 3.

So, using a wide vacuum pipe in the South Hall (say 300 mm diameter) will reduce the secondary particle production in the vacuum tube wall by the protons scattered on collimator No. 1. With a 300 mm vacuum tube one will have almost no interaction of single scattered protons with the tube wall from collimator No. 3 up to 27.5 m down streams.

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The vacuum pipe could run up from 30 m downstream of collimator No. 3, inside a concrete tunnel.

Tunnel dimensions : 1.30 wide inside, 2.0 m height, wall and roof 0.8 m thick, normal concrete.

To save space, the part of the tunnel wall (near the bubble chamber could be made of steel, 30 cm thick.

III. SHIELDING OF THE QUADRUPOLES, STORAGE RING :

During adjustments with the quadrupoles or by maloperation of magnet 1060, a part of the beam can hit the quadrupoles and parts of the storage ring magnet. Therefore additional side shielding is required near the quadrupoles and the storage ring. To reduce the volume of the shielding, the use of heavy concrete blocks is proposed.

Thickness wall near quadrupoles : 2.40 m , roof : 1.60 m.

To reduce the proton beam after its traversal of the target in the storage ring to a level of 10 particles/cm^2/sec., a steel beam catcher is proposed of 4 m. long and 2 x 2 m. The side shielding being closed to the target should be of 4 m. of heavy concrete and 2 m. height.

The side and top shielding around other parts of the ring depends on the shielding arrangement inside the ring. For example, the side shielding facing the Linac and bubble chamber could probable be made of normal concrete. A proposal for side shielding is shown on the attached drawing. The roof shielding could be made from standard concrete beams (0.4 x 0.8 x 8.0 m.). Those beams can carry a load of 3.5 tons/m length for a free space of 7.5 m. This means that one can load another 1 m. of heavy concrete on top of the beams which is likely to be sufficient.

IV. TOTAL SHIELDING REQUIREMENTS :

(excluding roof shielding ring, data as in 3 and 4).

normal concrete	60 m^3 (150 ton)
heavy concrete	290 m^3 (1000 ton)
steel	40 m^3 (320 ton)

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V. VACUUM :

To preserve the quality of the ejected beam over the long transport distance, one should maintain a vacuum of 10^{-1} torr in the beam pipe. This should be provided with an interlock device.

VI. ELECTRICAL POWER AND WATER COOLING REQUIREMENTS :

Storage ring magnet : 1.5 MW.
550 - 600 V =
2500 A.
cooling : 900 l/min.

2 quadrupoles (1m) : 450 A and 575 A.
Bending magnet 1060 : 950 A.
and fast ejection equipment up to SS 3.

VII. SAFETY INTERLOCKS :

7.1 Protection d-zone, transport tunnel and storage ring area :

The proposed beam stopper (BS), placed just before collimator No. 2, protects the d and following zones against radiations when the PS is operating. So, there will be a standard interlock system between the BS and the doors of the zones ; no access to the zone when the BS is open.

However, the BS does not provide sufficient protection when the beam is ejected towards the storage ring. The "no access to the zone condition" should exist as well when the ejection is operating and at the same time the bending magnet 1060 is powered. Violation of the no-access conditions should result in an automatic interruption of the current to magnet 1060.

7.2 Protection of equipment, control of radiation level outside shielding :

When the beam is maladjusted, a part of it will hit the quadrupoles and the storage ring magnet. One can not always avoid this situation but one should obtain an alarm when this situation occurs. A reliable alarm circuit should be developed using the signal from the existing type particle burst detectors.

Detectors giving alarm should be placed near the first quadrupole and in the d-zone.

Although the shielding should be designed to protect adjacent areas from radiation, one should place outside the shielding several radiation monitors with appropriate alarm circuits. A too high level reading on a radiation monitor should provide an alarm and should interrupt the ejection when the level remains high.

VIII. <u>MISCELLANEOUS</u> :

The existing beam observation station for the neutrino ejection near SS 3 will have to be modified.

A beam observation station should be installed in front of the beam stopper inside the ring area.to enable beam adjustments without activating materials in the South Hall.

It should be noted that no sharing with the neutrino experiment is possible with the proposed arrangements.

One should take the requirements for the storage ring into account when one rebuilds the shielding of the bubble chamber at the end of this year.

It is not certain that the present magnetic shielding of the bending magnet 1060 is sufficient for operation above 21.9 Wb/m^2.

Additional points, comments and criticisms should be sent to the undersigned.

Installation of the storage ring in the South Hall bubble chamber area is planned to start in February 1965.

J.H.B. MADSEN

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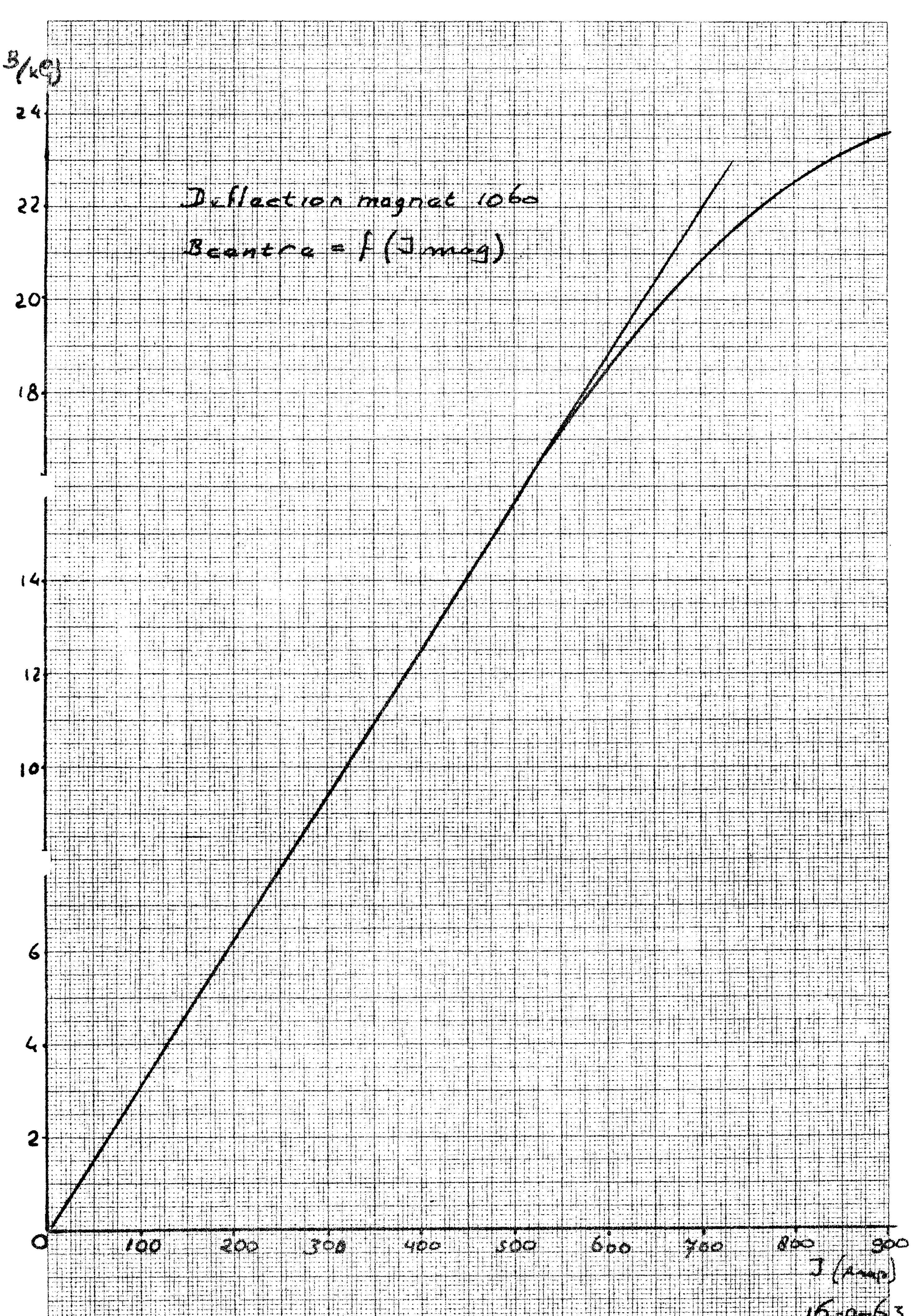
Deflection magnet 1060
Bcentre = f (Jmag)
B (kG)
24
22
20
18
14
12
10
6
4
2
0
100
200
300
400
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700
800
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J (Amps)
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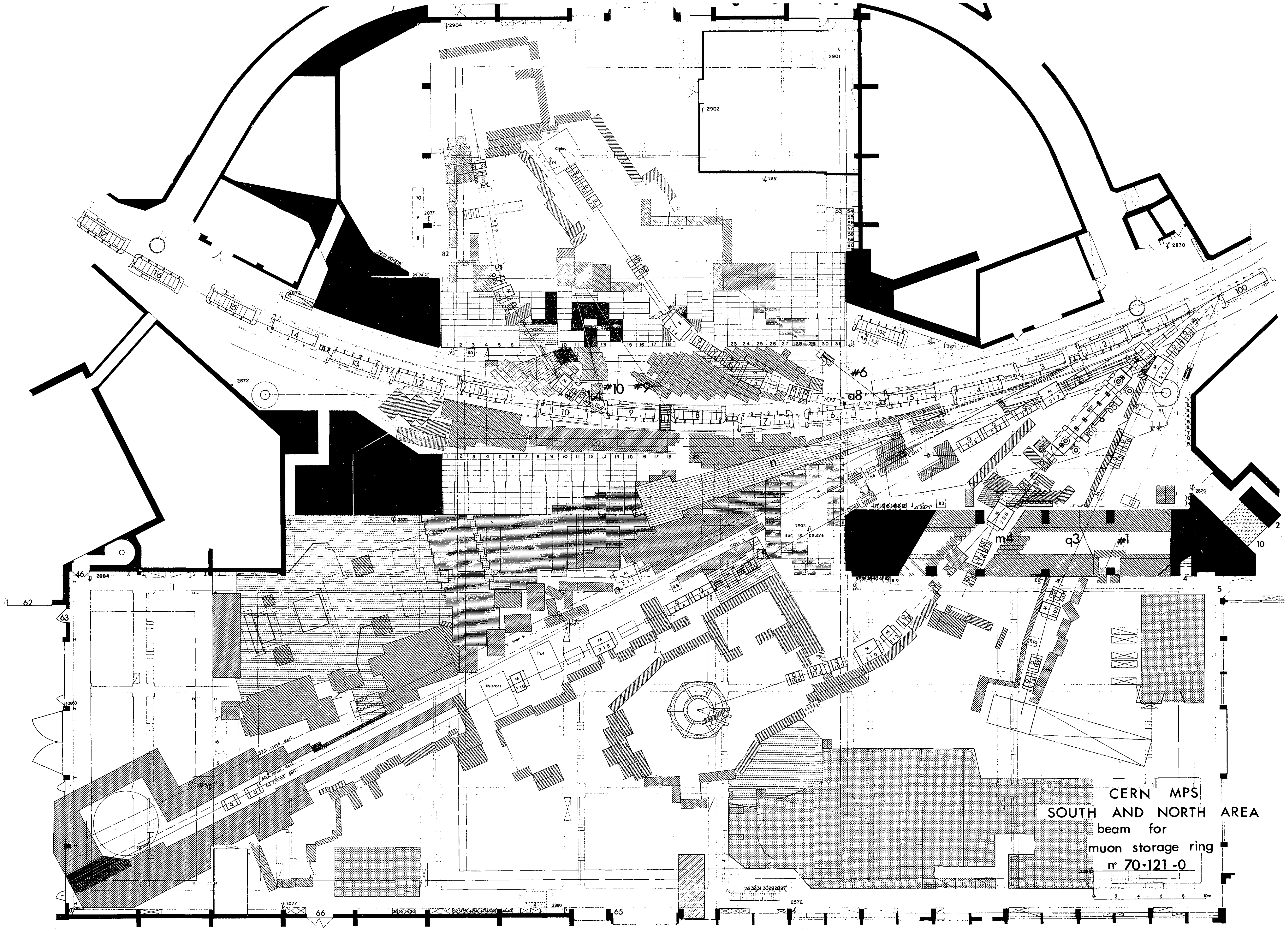
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