PS/Int. EA 60-16
5th November 1960

AN EXPERIMENTAL ARRANGEMENT OF THE HEAVY LIQUID BUBBLE CHAMBER IN THE NEUTRINO SEARCH

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ERRATUM

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Please, replace the 6 1/2 lines of paragraph 2.2. Sources of background at the bottom of page 15,

by

Paragraph 3.3. Operating arrangement in the chamber area.

"The erection of a thick blockhouse around the propane bubble chamber in the presently available area introduces serious space limitations. The example of the space occupied by the E.P. propane bubble chamber team during their runs in Saclay and at CERN and our experience during assembling indicate that a total free area of some 150 m^2 is a minimum for safe and orderly work".

1. INTRODUCTION.

A large heavy liquid bubble chamber is a convenient instrument for an attempt to detect reactions induced by high energy neutrinos produced by the C.P.S. Such an experiment involves a major effort in time and expenditure and its planning must be supported by a detailed study of the physical layout, the practical problems involved in the erection of the shielding, the financial implications and the effect on the general nuclear physics programme for the C.P.S.

This report proposes an experimental arrangement of our 500 l heavy liquid bubble chamber in its assembly region in the South Hall and presents a study of the problems mentioned above. The general shielding considerations of a previous report (PS/Int.EA 60-10) are completed with estimates of the intensity of possibly confusing background from neutrinos penetrating the shielding after multiple scattering. A detailed arrangement of the different shielding materials is worked out on the basis of information from the C.P.S. Machine Group and on criteria of availability, cost and erection facilities. The space requirements of the equipment around the chamber are studied and floor loading problems are investigated.

Tentative estimates of cost and time schedules, including auxiliary tests for the preparation of the experiment, are presented.

2. SHIELDING CALCULATIONS.

2.1. Muon shield.

The calculations presented in this chapter are based on the layout shown in Figs. 1,2 and 3. A detailed discussion of those diagrams is given in chapter 3.

The shielding in the direct line of sight target - bubble chamber must have such a thickness, that no muons can reach the chamber. Therefore the cutoff momentum [1] of the muons must be slightly above 20 GeV/c and we have chosen 20.5 GeV/c as a design figure for the shielding layout. An extrapolation of Fig. 2.9.4 in Rossi's book [2] shows, that this corresponds to a total shielding thickness of 10'500 g/cm^2 of steel. The same figure is valid for baryte, since this is mainly bariumsulfate so that it has roughly the same Z as steel. The bubble chamber magnet itself is equivalent to 500 g/cm^2. This leaves then for the muon shield a thickness of 28.5 m. The latter figure should be considered accurate to perhaps 10 o/o and within these limits it will have to be adjusted by direct experimentation. If the thickness of 28.5 m would not be sufficient one could either place some extra baryte blocks against the end wall of the decay tunnel, or lower the energy of the P.S. by some 5 o/o to 10 o/o.

2.2. Sources of background.

The particles which could produce spurious events, similar to neutrino reactions, are neutrons with energies above a few hundreds MeV. The absorption length of steel or baryte for high energy nucleons has been measured [3,4] as 140 g/cm^2. For an attenuation by a factor of 10 one therefore needs 93 cm of baryte or 42 cm of steel. The attenuation in the direct line of sight target - bubble chamber is about 10^{-30}, so that essentially no neutrons will pass through the muon shield in the same direction as the neutrinos.

The confusing background comes from particles, which have been scattered through the side walls or through the roofs of the decay tunnel and of the shielding bridge. Such particles can be scattered once or several times more against the walls or roof of the South Hall, so that they can enter the bubble chamber from above or from the side, where the shielding thickness is much smaller. The main difficulty of the shielding design is to make a reliable estimate of this background.

In general it will be possible to eliminate spurious events on the basis of kinematics. Any V - type event such as produced in the reactions

$$\nu + n \longrightarrow p + e^-$$
$$\nu + n \longrightarrow p + \mu^-$$

must be consistent with a direction of the incoming neutrino, which is known within 50 mrad. These 50 mrad represent only a fraction 2×10^{-4} of the total solid angle $4 \cdot \pi$ and therefore this should be a very strong rejection criterion, since most background neutrons will probably come from above and from the sides. In view of the very small number of neutrino events to be expected, however, the neutron background should be made as low as is practically possible, in order to make the identification of neutrino events unambiguous.

2.3. Flux of background particles entering the South Hall.

The flux of secondaries emitted from the target and hitting the shielding walls can be estimated with the help of Hagedorn's [5] curves. In all calculations which follow we shall assume, that 3×10^{11} protons per pulse interact in the target, and all background fluxes will be given per pulse. Let us first calculate, in order to demonstrate the method, the flux of particles entering the South Hall through the wall KL of the decay tunnel which has a thickness of 3 m baryte. This wall is hit by about 2×10^{10} secondaries. These are mainly pions and nucleons in roughly equal numbers with an average energy of about 6 GeV. The fraction of the particles with energies above 10 GeV is 3 o/o.

We now assume, that such a secondary particle interacts in some representative point P_1 in the side wall, and estimate the probability, that in this interaction an energetic particle is produced in a direction, whose projection on the hori ontal plane makes an angle α_h with the line target bubble chamber. For this we can use a curve, given by Kalbach et al.[6], which shows the number of lightly ionising secondaries from nuclear stars per unit interval of projected angle α, for 6.2 GeV protons in emulsion. The lightly ionising particles produced at large angles will be mainly pions, whereas the neutron background in the bubble chamber will be mainly produced by nucleons. The average and maximum kinetic energy in the c.m.s. of the nucleons as predicted by the statistical model[7] is smaller than that of the pions, so that the angular distribution in the laboratory system of the nucleons will have a stronger peaking in the forward direction than that of the pions. From the data given by Cork et al.[8] it follows that the angular distribution of the elastically scattered nucleons, which have the highest energy, is much more peaked in the forward direction than the curve given by Kalbach et al., so that the latter can be considered as a pessimistic estimate. Normalising this curve to a total of 3 secondaries per reaction, we obtain the following particle fluxes:

interval of α_h	$5^\circ - 15^\circ$	$15^\circ - 25^\circ$	$25^\circ - 35^\circ$	$35^\circ - 45^\circ$	$45^\circ - 55^\circ$	$55^\circ - 65^\circ$
particle flux	10^{10}	4×10^9	2×10^9	10^9	4×10^8	10^8

The attenuation in the wall KL is found by measuring the thickness of baryte the particles have to traverse. In this way we find for the intensity of tertiary particles entering the South Hall which are produced in single interactions in the part of the wall KL adjacent to the decay tunnel, the following figures :

interval α_h	5° - 15°	15° - 25°	25° - 35°	35° - 45°	45° - 55°	55° - 65°
particle flux	10^{-9}	0.2	2×10^2	3×10^3	10^4	10^4

The average energy of these particles is of the order of 1 GeV to 2 GeV. They are accompanied by a 10 times higher flux [9] of degraded particles which have a history of more than one nuclear interaction in the wall KL. However these degraded particles have a lower energy. As will be shown below, at least one more large angle scattering is required for a particle to enter the bubble chamber from the side. Therefore these degraded particles will not have sufficient energy to simulate a neutrino event and we can neglect single scatterings over angles, larger than 60° in the wall KL. Not only is the scattering probability small, but also the energy of the outgoing particle is so low that it falls in the category of degraded particles.

The roof of the decay tunnel is equivalent to 4.4 m of normal concrete and is hit by about 2×10^{10} secondaries. However the part of the roof of the shielding bridge above the P.S. ring itself has a thickness of only 1.8 m of normal concrete. Fortunately a good part of it is hidden behind the yoke of unit 5, but even so it is hit by about 4×10^{10} secondaries. Therefore we shall assume, that a 1.6 m thick layer of normal concrete blocks is placed on top of the shielding bridge. In the same way as for the wall KL we can estimate the flux of energetic tertiary particles from single interactions in the roof in various directions, whose projection on a vertical plane makes an angle α_v with the line target.- bubble chamber. This gives the following figures:

interval of α_v	5° - 15°	15° - 25°	25° - 35°	35° - 45°	45° - 55°	55° - 65°
flux through roof of decay tunnel	10^{-8}	0.5	2×10^2	3×10^3	5×10^3	5×10^3
flux through roof of PS ring	4×10^{-4}	2×10^2	10^4	2×10^5	2×10^5	10^5

It is obvious that the roof of the P.S. ring is by far the strongest source of background radiation. We therefore assume, that a lead roof, some 40 cm thick is placed above straight section 5 and along the front side of unit 5, in such a way that it shields completely the thin part of the P.S. roof from the direct radiation coming from the target. This would reduce the flux of particles passing through the PS roof by an additional factor 10. In that case, the total flux, passing through both roofs, is

interval of α_v	$5^o - 15^o$	$15^o - 25^o$	$25^o - 35^o$	$35^o - 45^o$	$45^o - 55^o$	$55^o - 65^o$
flux through roofs	4×10^{-5}	20	10^3	2×10^4	3×10^4	2×10^4

The flux of background particles, passing through other parts of the P.S. shielding can be neglected compared with the sources of background considered above.

2.4. Shielding around the bubble chamber.

This shielding has been kept rather thin, in order to keep the space requirements down and the floor loading within acceptable limits. The North side of the bubble chamber is well shielded by a large earth bank, while the flux of neutrons coming from the back is certainly small. Most of the background will therefore come through the South wall and the roof of the bubble chamber blockhouse. We now draw a number of lines through the South wall and roof, passing through the centre of the bubble chamber and making angles β_h in the horizontal plane and β_v in the vertical plane with the line target - bubble chamber. The attenuation factors in these directions, taking into account the bubble chamber magnet, are given in the following table.

β	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°
attenuation in horizontal plane	10^{-25}	10^{-15}	4×10^{-12}	10^{-8}	5×10^{-6}	10^{-4}	10^{-3}	2×10^{-3}	3×10^{-3}	3×10^{-3}	3×10^{-3}
attenuation in vertical plane	10^{-16}	3×10^{-8}	5×10^{-6}	5×10^{-6}	5×10^{-5}	10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}

2.5. Energy degrading in scattering.

From the data given above, it follows that particles must be scattered over at least 30° in the walls of the decay tunnel or roof and must enter the bubble chamber at angles β in excess of 40° in order to have a sufficient probability to pass through the shielding. Scatterings over large angles give a large reduction in energy. Experimental data or theoretical calculations on the energy spectra for large angle scattering are practically non existent. In order to get some idea of the situation, we have therefore calculated the kinetic energy of a nucleon which is elastically scattered through an angle ϑ in the lab. system in an elastic nucleon-nucleon collision. These data, for various energies of the primary nucleon are given in the following table

ϑ_{lab} \ kin. energy of primary nucleon	24 GeV	6 GeV	2 GeV	1 GeV	0.4 GeV
0°	24.0 GeV	6.0 GeV	2.0 GeV	1.0 GeV	0.40 GeV
10°	17.6	5.4	1.9	1.0	0.38
20°	8.6	3.9	1.6	0.8	0.35
30°	4.8	2.6	1.2	0.7	0.28
40°	2.4	1.6	0.8	0.5	0.21
50°	1.0	0.9	0.5	0.3	0.15
60°	0.7	0.45	0.3	0.2	0.08
70°	0.2	0.20	0.1	0.1	0.03
80°	0.1	0.05	0.03	0.02	0

Any secondaries which are produced in a reaction or nucleons which are scattered in an inelastic collision will have lower energies than those given in the table. This then justifies our previous assumption that all particles entering the South Hall in directions which make angles larger than 60° with the line target-bubble chamber, can be neglected.

2.6. Neutron flux in the bubble chamber.

Using the data given in the previous paragraphs we have calculated the neutron flux in the bubble chamber under the following assumptions.

1. The average energy of the particles entering the South Hall through the P.S. shielding lies in the range of 1 GeV to 2 GeV. The maximum energy in case of elastic scattering in the target and in the P.S. shielding is taken as 6 GeV, the flux of particles with energies above 6 GeV being less than 0.1 o/o of the total.

2. Only elastic nucleon-nucleon collisions are considered in the South Hall since by inelastic collisions the energy is too much degraded.

3. One half of all nuclear interactions is taken as elastic.

4. To calculate the angular distribution of the elastically scattered nucleons in the laboratory system, the distribution is taken as isotropic in the c.m.s. This is probably rather pessimistic.

5. The maximum angles over which nucleons can be scattered without too much energy degradation are

   for single scatterings : 70°
   " double " : 100° (e.g. $50^{\circ} + 50^{\circ} + 50^{\circ}$ or $60^{\circ} + 40^{\circ}$)
   " triple " : 120° (e.g. $50^{\circ} + 30^{\circ} + 40^{\circ}$)

6. Background originating in the roof of the P.S. shielding only passes through the roof of the bubble chamber, while background from the wall KL only passes through the side wall of the bubble chamber.

7. In the vertical plane scattering occurs against the roof and air molecules (skyshine), while in the horizontal plane the walls and floor are the main sources of scatterings.

8. Reasonable solid angles, which take somewhat into account the geometry of the South Hall have been used to calculate the geometrical factors which enter into the scattering probabilities.

In this way we find the following numbers of neutrons with energies above a few hundreds MeV, (per 3×10^{11} protons interacting in the target) which enter the bubble chamber from the side and from above

	from the side	from above
from single scattering	10^{-9}	2×10^{-6}
from double scattering	5×10^{-5}	5×10^{-5}
from triple scattering	3×10^{-5}	3×10^{-6}

The maximum energy of the neutrons, assuming that all interactions in the target and in the shielding are elastic scatterings, lies in the range from 0.8 GeV to 1 GeV.

Regarding the relative magnitudes of the figures given in the table the following comments can be made. The background intensity from single scatterings in the horizontal plane is very low, since these particles must pass through part of the muon shield which has been extended somewhat to the South. For double scatterings both planes are roughly equivalent, while for the triply scattered particles, which can enter the blockhouse for values of β up to 90°, the attenuation is 10 x less in the horizontal plane than in the vertical plane.

In general the geometrical factors decrease for higher order scatterings but it allows the neutrons to enter the bubble chamber more from the side, where the shielding thickness is smaller. Therefore the intensity of triply scattered neutrons is still comparable to that of double scattered ones. Since, however, the triply scattered neutrons can already enter the bubble chamber through the weakest part of the shielding the background from fourfold scattered neutrons can be neglected compared with the figures given above.

In the course of this calculation a number of assumptions had to be made and in general we have tried to remain somewhat on the conservative side in our estimates. By using the same assumptions everywhere it has been possible to compare in a realistic way the relative merits of various amounts of shielding in different places. Moreover it appears very encouraging that the total calculated number of background neutrons per pulse in the bubble chamber is of the order of 10^{-4}.

3. PROPOSED SHIELDING LAYOUT.

3.1. General comments.

The disposition of large amounts of shielding around the bubble chamber and in the South Hall raises a number of practical problems which are mainly related to the structure of the building(available space and floor loading limits and to existing facilities (handling).

The concentration of a load of 6000 tons in the vicinity of the C.P.S. might raise some concern as to the danger of a local sagging of the ground, but it looks improbable that the region of the molasse, which carries the supporting pillars of the C.P.S., will be much affected. In fact the Survey Section of the Machine Group estimates that the pillars would not sag more than 0.8 mm. The induced tilt of the neighbouring wall of the South Hall and the displacement of the crane rail will not be serious, according to the architects.

The specific floor loading of a 5 m layer of baryte concrete of density 3.6 is 18.0 tons/m^2 which is very near the nominal allowed figure of 20 tons/m^2. In regions where steel or lead would be used the above figure is exceeded. In this respect special attention must be paid to the side walls of the decay tunnel, the bubble chamber blockhouse and the free passages, where the load of thick roofs is supported. This applies particularly to the places where these walls are in the vicinity or on top of floor trenches. The present proposal has been worked out on the basis of the floor specifications guaranteed by the architects. However, the maximum nominal floor loading is exceeded by 45 o/o under the supports of the blockhouse roof.

Floor trenches represent a weak point in the shielding: their filling with bags of baryte sand may have to be envisaged at places.

Since the relevant quantity for this shielding is the total mass of material on each particular path of possible access to the chamber, the choice of the shielding material is determined mostly by considerations of economy, availability and floor loading. Therefore wherever space and mechanical strength allowed it, normal concrete has been preferred to baryte concrete and this, in turn, to steel and lead.

The layouts discussed in sections 3.2 and 3.3. consider the requirements of the heavy liquid chamber operation. The possibility and implications of an additional counter arrangement are considered in section 3.4.

3.2. Layout in the South Hall.

The general layout is shown in Fig. 1. The shielding can be divided into a number of parts which will be discussed separately.

a) Separating wall inside the ring.

The experiments which are presently in progress at the C.P.S. mainly use high energy beams from target 1 and 2. Therefore a substantial fraction of the shielding at beam height in the region EF of the C.P.S. shielding wall has been removed and large collimators have been made for these beams. When not in use these collimators are closed rather superficially by placing lead blocks in front of them. It is doubtful, that this situation would give sufficient shielding for the neutrino experiment. On the other hand it must be easy to open the collimators in order to change over quickly from a neutrino run to other experiments

During a neutrino run we plan to monitor the bubble chamber at regular intervals of time by sending a beam of charged particles through it, which comes from target 1 or 2 and is deflected by the bending magnet BM2 into the bubble chamber. The collimator for this beam in the region EF of the C.P.S. shielding wall could be closed or opened quickly with a lead block actuated by an hydraulic jack. We also hope, that it will be possible to devise procedures for simultaneous machine utilisation by using two targets flipping at different times during the accelerating cycle.

It is proposed therefore to build a shielding wall, 1.6 m thick and 3.2 m high, inside the C.P.S. ring, along the South side of the pion decay path to shield the region EF as much as possible from direct radiation from target 5.

b) Additional roof shielding.

It has been shown in chapter 2, that the roof is by far the weakest part of the C.P. S. shielding. It is proposed, therefore, to place an additional layer of concrete blocks on top of the shielding bridge and to build a lead roof above straight section 5.

As shown in Fig. 1 the concrete blocks on top of the shielding bridge have a thickness of 1.6 m and a total weight of about 1000 tons.

If such a load were evenly distributed over the total area of the shielding bridge it would remain well within the permissible loading specified by the architect. Since it is mainly concentrated on the south half of the shielding bridge, some further studies are being made, in order to investigate its practical implications.

The lead roof above straight section 5 would have a thickness of 50 cm and would extend a long part of the front side of unit 5. Its weight is estimated of the order of 15 tons to 20 tons.

Since the construction of the lead roof above straight section 5 will make the region around the target rather inaccessible, one could possibly wait with installing it, until actual measurements with the bubble chamber have given more definite data about the intensity of the background passing through the C.P.S. roof.

c) The decay tunnel.

A cross section of the decay tunnel is shown in Fig. 2. Its South wall KL is 3 m thick and can be made of the baryte blocks which are removed from the main C.P.S. shielding, Its roof outside the C.P.S. shielding bridge consists of 4 m of concrete. This is supported by a layer of 3 m long steel beams, which are already available in CERN. The concrete roof should stick out about 50 cm beyond the wall KL in the South direction in order to give everywhere around the decay tunnel an equivalent shielding thickness of at least 3 m of baryte. For the same reason the shaded areas must be filled with small or specially cast baryte blocks.

A practical problem is, that the large triangular supports for the rails of the 20 ton cranes, which are fixed to the shielding bridge, must be built into the roof of the decay tunnel. This will complicate the handling of the larger shielding blocks and will also require a substantial quantity of small blocks.

d) The muon shield.

The shielding in the direct line of sight between the end face of the decay tunnel and the bubble chamber must have a thickness of at least 10 Kg/cm^2 to stop all muons. To keep its thickness within reasonable limits it must be made of baryte, but since the floor is made of concrete, it does not help much to place baryte more than 0.5 m out of the direct line of sight between decay tunnel and bubble chamber. The last 5 m in front of the bubble chamber should be made of baryte up to the maximum height of 4.8 m, in order to give increased shielding against the background passing through the roof of the shielding bridge.

The height of the muon shield near the decay tunnel is 6.5 m, and in the region covered by the 20 ton cranes, 4.8 m. This allows the 20 ton cranes to pass over it. However about half of the muon shield is under an overchanging roof in the South Hall and another part is near the walls outside the range of the crane hooks. Therefore about three quarters of the muon shield must be put in position without using a crane.

The cable trenches in the South Hall need special attention. As shown in Fig. 1 the standard blocks can practically always be arranged in such a way that the cable trenches are spanned by large blocks, so that no special steel covers are required for them. However, the cable trenches under the shielding wall and the East-West cable trenches under the muon shield must be filled as much as possible with shielding material.

In order to monitor the correct operation of the bubble chamber, it is desirable to send at regular intervals of time a pulse of charged particles through it. Therefore it is planned, to install in the muon shield a small collimator (along the line AA'), that can be opened or closed within a few seconds. This could be done by using a pipe with a diameter of a few cm, filled with mercury, or by using some kind of pneumatically or hydraulically operated shutter system.

2.2. Sources of background.

The particles which could produce spurious events, similar to neutrino reactions, are neutrons with energies above a few hundreds MeV. The absorption length of steel or baryte for high energy nucleons has been measured [3,4] as 140 g/cm^2. For an attenuation by a factor of 10 one therefore needs 93 cm of baryte or 42 cm of steel. The attenuation in the direct line of sight target - bubble chamber is about 10^{-30}, so that essentially no neutrons will pass through the muon shield in the same direction as the neutrinos.

The layout presented in fig. 3 takes into account only the space occupied by some essential parts of the equipment and by their operators. It was assumed that working space for urgent repairs and maintenance, a dark corner for camera loading and for development of test film, a table for quick scanning and some 10 cupboards of tools, instruments and spares, covering altogether about 40 m^2, could be made available in the immediate vicinity; (partly in a temporary shack on the road, and partly in the E.P. bubble chamber region). Special emergency arrangements have been considered to cope with space requirements for unloading and stocking shielding materials, like the long steel beams and the baryte blocks of the roof, which have to be removed for handling the chamber with the crane.

The inside length(10.20 m) and height (3.20 m) of the blockhouse are determined by the minimum space requirements of the bubble chamber in the magnet. Access to the magnet coils and to the main nitrogen connections, and major maintenance operations of the chamber require partial removal of the roof.

The inside width is adequate for the chamber, the temperature control system, which can operate properly only at that position, and the flash H.T. supply.

The position of the back wall is also determined by the necessity of keeping away from the longitudinal trenches.

The thickness of all walls is 1.60 m: for the front wall this figure is not relevant, on account of the large amount of shielding in front of it, but it is convenient to fill the space between the supports of the crane. On the North side the thickness of the earth bank, 6 m high, provides adequate shielding. On the South side, it would be possible to increase the shielding thickness by placing an array of baryte blocks in the E.P. area.

The roof consists of a layer of steel beams 40 cm thick, 8 m long, which support 2 layers of 80 cm and 40 cm thick baryte blocks respectively. The replacement of the baryte blocks by steel could be considered if floor loading and finance would allow it. The addition of another layer of 40 cm baryte blocks would make it impossible to open part of the roof without opening a way out on one side and taking the parts removed away from the area.

A special crane hook will be needed to make full use of the available free height. A difficult problem is the one of covering the region along the north wall, where a passage must be left on the trench in front of the electrical switchboards. The roof in that region could consist of a fixed layer of 3 m long steel-bars, unaccessible to the crane, supported on one side by a steel frame close to the north wall, and resting on the long steel beams on the other side.

In both cases an additional load is put on the first part of the shielding wall (pillars 1 and 2 in fig. 3). Appendix A contains detailed calculations of floor loading.

The magnet cooling water, the nitrogen ducts, the propane piping system and pressure equalizing system, and a number of control cables would pass through suitably oriented ducts in the back wall. The magnet d.c. supply cables would penetrate under the front wall.

Easy access and free space must be left on all sides of the chamber and especially in front, for camera handling and observation, and in the back for maintenance of the valves and replacement of the flashes. The place for an operator is foreseen in front of the cameras. The passage on the north side provides access to the electric switchboards beyond the gas-tight wall as well.

It is important that the erection of the blockhouse does not require to remove the chamber or major parts of the system.

In the layout fig. 3 some distance is left between the chamber and the front wall, to make erection easier. For the same purpose, the 3 m long rails in front and the 1 m long rails in the back of the chamber system can be temporarily removed.

Until completion of the west shielding wall, an unloading area 3 m wide and 6 m long in front of the door can be kept free by displacing light equipment only. Two thirds of this area are covered by the 20 ton crane. Some 30 tons of steel beams can be stored temporarily on top of the shielding wall on the south side without exceeding floor loading limits.

3.4. Implications of an additional counter arrangement.

Apart from the CERN heavy liquid bubble chamber group there is a CERN counter group that plans to take part in the neutrino search with a large hodoscope type counter, which is at present under construction. We have therefore investigated how both experimental arrangements could be combined most conveniently in the very limited available space and propose the layout of Fig. 4 as the most suitable solution.

The hodoscope counter is placed in a tunnel through the muon shield. About 4 m of baryte is left between the bubble chamber and the counter tunnel In this way the shielding of both detectors against background neutrons is practically independent. For certain repairs on the bubble chamber the use of the crane is required, so that part of the roof of the blockhouse must be removed to provide access for the crane hook. In such cases the background conditions in the counter tunnel remain unchanged and the neutrino search could continue with the hodoscope counter alone. At the position indicated in fig. 4 the hodoscope counter is under the hook of the 20 ton crane of the South Hall. This would be very convenient during its assembly, since its total weight is estimated as 50 tons.

The space left open in Fig. 4 for the counter is 4.8 m wide, 2.8 m high and 3.2 m deep. It has access from the South through an 0.8 m wide tunnel in the muon shield and on the North side from the bubble chamber area through the tunnel along the electrical switchboards.

In this layout the E.P. bubble chamber could remain in its present position. A small part of the E.P. area would be required for optical facilities and movable equipment of the CERN bubble chamber group, but the E.P. bubble chamber could remain in operation condition and could continue to participate in the C.P.S. nuclear physics programme during 1961.

Since the counter must also be shielded against muons, the decay tunnel becomes about 6 m, that is 15 o/o, shorter. It would just extend over the total thickness of the C.P.S. shielding wall under the shielding bridge, but would not extend into the South Hall. Under these conditions all shielding blocks can be oriented in the East - West direction, which would very much simplify the erection of the part of the muon shield against the shielding bridge.

The necessary independence of the two detectors, combined with a minimum of disturbance to the E.P. bubble chamber could hardly be obtained in a different way. It has been suggested that the counter could be placed behind the bubble chamber and the bubble chamber blockhouse extended to cover also the counter. However in such an arrangement the problems of floor loading and space distribution could not be solved without drastic provisions, such as reinforcing of trench walls and complete evacuation of the space presently occupied by the E.P. bubble chamber.

It would also be necessary to take unloading space for shielding elements and equipment in the E.P. area and the dividing wall would have to be demolished. The whole system for distribution of nitrogen and propane would be placed in the E.P. area, together with storage, servicing and maintenance facilties. Space in the same area should be found also for auxiliary electronics of the counter group.

Obviously it would not be possible for the counter group to have access to the chamber erection area before satisfactory chamber testing and transfer of the operating equipment into the neighbouring area.

4. FINANCIAL IMPLICATIONS AND TENTATIVE PROGRAMME.

4.1. Shielding material.

The total shielding requirements corresponding to the layout in Fig. 1, are as follows :

a) Shielding in the South Hall

Normal concrete : 3500 tons, of which at least 3/4 could be blocks of maximum standard size i.e. 2.4 x 1.6 x 1.6 m^3

Baryte concrete : 3000 tons, of which at least 3/4 could be blocks of maximum standard size i.e. 2.4 x 1.6 x 0.8 m^3

A small percentage of special blocks to fill holes and corners is needed too.

Steel : 100 tons of 3.00 x 0.22 x 0.07 m^3 beams

b) Blockhouse

Baryte concrete : 1050 tons, of which 240 tons are the largest standard blocks, 650 tons must be blocks of 1.6 x 0.8 x 0.8 m^3 and about 160 tons must be blocks of 1.6 x 0.8 x 0.4 m^3

An extra 250 tons of packed steel should be kept as a reserve to improve roof shielding

Steel : 280 tons in beams, 8 m long and 0.4 m thick.

50 tons in beams of 3.00 x 0.15 x 0.07 m^3.

According to information supplied by the PS Machine Group, an adequate stock of blocks of ordinary concrete and of 3 m steel beams is available, and some 2000 tons of baryte concrete might be taken with great effort from the existing stock by the end of the year.

The remaining 2000 tons of baryte concrete might be produced at a rate of 100 tons a week starting from December 60 by an increase of the block making facilities which the M.G. considers to be reasonable.

From preliminary investigations carried out by the Machine Group, a delivery time from 4 to 6 months should be expected for the long steel beams of the blockhouse roof.

A computation of costs based on price estimates given by the Machine Group appears in the following table. The cost of all baryte blocks and steel beams is counted since the ones taken from stock will have to be replaced. However, this cost should not be considered strictly as a charge due to the neutrino experiment, since the shielding elements will remain afterwards permanently in the stock of the P.S. machine for other experiments.

Price of baryte blocks	4000 t	at	150 Fr./t	600'000 Fr.
Price of steel beams	280 t	at	700 Fr./t	200'000 Fr.
			Total	800'000 Fr.

The accomodation of a counter team as shown in fig. 4, would of course require some additional shielding. The only significant item would be the steel beams for the roof of the counter house. For a covered surface of 20 m^2 their total weight would be about 80 tons.

4.2. Erection and experimental tests.

The existence of part of the shielding material in CERN stocks would allow erection to be started at the earliest date compatible with the experimental programme of the P.S. machine.

With the expected increase of the production facilities 2000 extra tons of baryte blocks could be made by the end of April 61. There seems to be a reasonable probability that the long steel beams could be delivered by that date too. According to these estimates, materials would be available for completion of the shielding arrangement during the month of May.

The decay tunnel can be constructed only during a long shutdown, since a large number of the blocks under the prestressed bridge must be rearranged.

It would be useful to do this installation, which does not depend on external deliveries, at an early date. Some delay would result from the combination with other important works to be performed on the machine, such as the installation of the ejection cavities, for which present forecasts indicate May as the most probable time.

The use of target 5 for the neutrino run necessitates the removal of the sextupole and octupole lenses in straight section 5. In order to allow background studies it would be important to have this done at the earliest machine shutdown next December.

For the same reason it would be useful to have the separating wall inside the ring tunnel erected as soon as possible. However this work too may have to be timed with the machine shutdown for ejection installation.

The CERN propane bubble chamber will undergo systematic tests and engineering runs during a few months and it is hoped to be ready for scientific work in March or April. The blockhouse in the bubble chamber area, for which medium size baryte blocks and long steel beams are required, should be erected at that time.

In order to test the regular operation of the chamber and to study its performance, some beam of charged particles will be sent through it during the engineering runs. A 2 metre bending magnet (BM 2 in fig. 1) will deflect into the chamber a beam of positive or negative particles up to 2 GeV/c, emitted by a target in straight section 1. This beam would not interfere with any of the existing ones and would pass along the outside of most of the neutrino shielding.

It has been suggested by F. Krienen that a systematic study of the background before erection of the blockhouse would be useful. Krienen considers that the thickness of its roof and walls can be decided from the number of neutron events and their angular distribution. This work could be done conveniently with the bubble chamber during its engineering runs.

For such runs, target 5 should be used, while all collimators and obvious weak points around the machine should be closed. It is estimated that some 10 hours of operation would provide sufficient information. Obviously this study should be specially interesting after the construction of the neutrino channel. It would also provide a useful training to the identification of spurious events.

It would be convenient to start the erection of the shielding in the South Hall from the regions along the North wall, and along the gas-tight partition where it would not interfere with any existing beam. The region initially occupied by the CERN cloud chamber should be kept free as long as possible.

During erection of this shielding the observation of μ meson background in the chamber shall be used to adjust the total thickness of the muon shield.

B. de Raad
L. Resegotti

/fv

Distribution : (open)
Directorate
Parameter Committee.
PBC Group

APPENDIX A

Floor loading around the propane chamber blockhouse.

The floor specifications allow a distributed load of 20 tons/m^2 everywhere and a point load of 20 tons in a circle of 20 cm diameter in the centre of an area of 1 m^2.

In the case of the edge of a shielding wall or pillar supporting the roof, this specification allows to assume that an empty strip some 50 cm wide in front of the edge can be counted as part of the load sharing area (provided, of course, it does not fall on a trench).

Since the wall itself will share the edge roof load on a width of 1 m at least at is base, the calculations of floor loading can be made by adding all loads from roof and walls on each square of 1 m^2 near the edge and considering them shared by 1.5 m^2 of floor,

The calculated loads correspond to the layout in fig. 3.

1. Side walls :

Load per metre length of 1 m wide strip at the edge

a) Steel beams 8 m long 0.4 m high, 4.0 x 1 x 0.4 x 7.8 = 12.5 t/m

b) Baryte cover 1.2 m high, 4.0 x 1 x 1.2 x 3.6 = 17.3 t/m

c) Baryte wall 3.2 m high and side blocks

3.2 x 1 x 1 x 3.6 = 11.2 t/m

1.2 x 0.5 x 1 x 3.6 = 2.2 t/m

Total : 12.5 + 17.3 + 11.2 + 2.2 = 43.2 t/m

Equivalent specific load $\frac{43.2}{1.5} = 28.8$ t/m^2

2. Pillar 2

a) One quarter of the load of 6.4 m of passage cover. The passage is 1 m wide.

Steel beams	$\frac{1}{4}$ x 6.4 x 1. x 0.15 x 7.8	= 1.9 t
Baryte	$\frac{1}{4}$ x 6.4 x 1. x 0.8 x 3.6	= 4.6 t

b) Half the load of 6.4 m of roof span

Steel beams	$\frac{1}{2}$ x 6.4 x 1. x 0.4 x 7.8	= 10 t
Baryte	$\frac{1}{2}$ x 6.4 x 1. x 0.8 x 3.6	= 9.2 t

c) Baryte pillar 3.2 x 1. x 1.x 3.6 = 11.5 t

Total 1.9 + 4.6 + 10 + 9.2 + 11.5 = 37.2 t.

Equivalent specific load $\frac{37.2}{1.2}$ = 31 t/m^2

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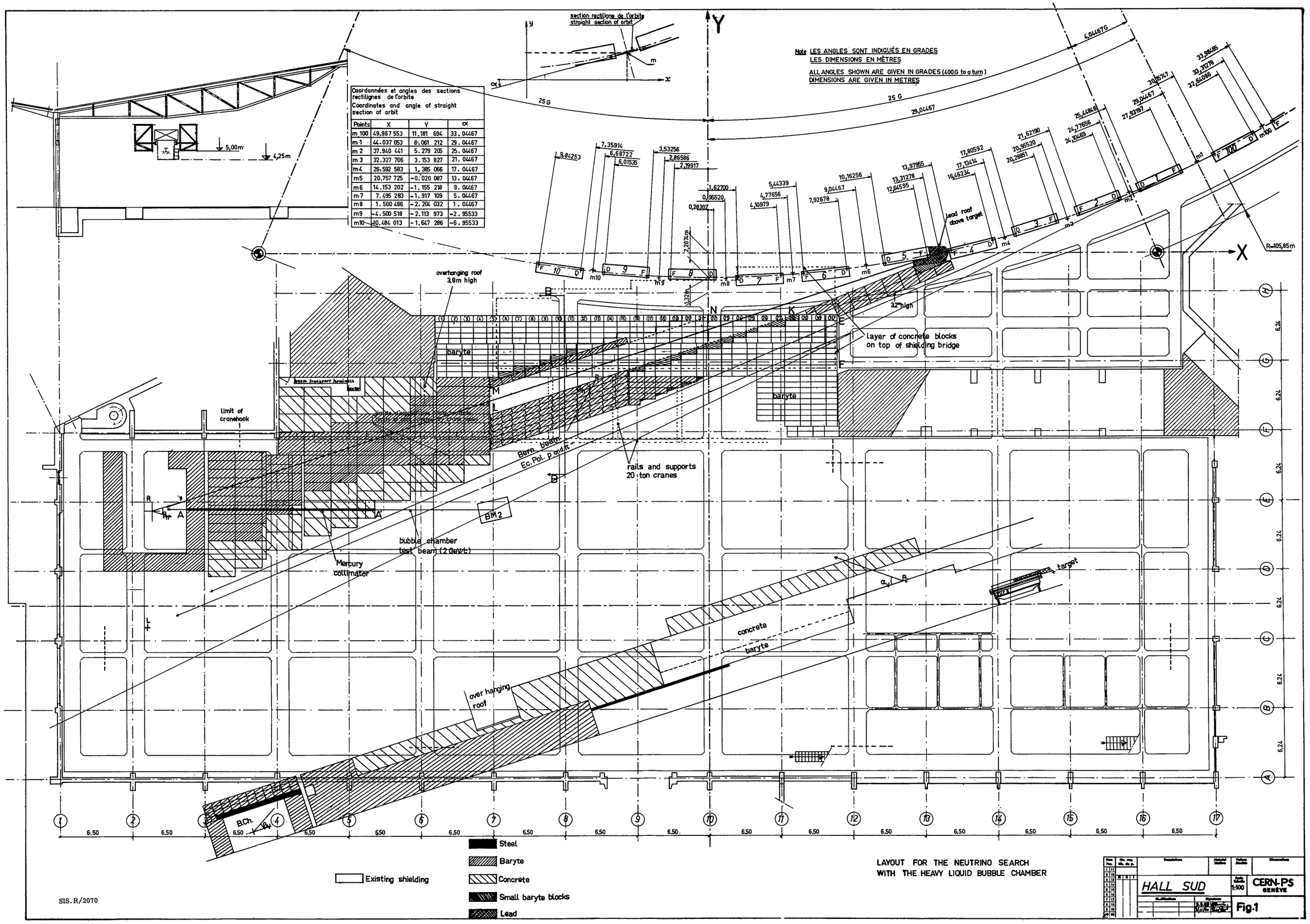


Coordonnées et angles des sections rectilignes de l'orbite Coordinates and angle of straight section of orbit			
Points	X	Y	α
m 100	49.967 553	11.181 694	33.04467
m 1	44.037 053	8.061 212	29.04467
m 2	37.940 441	5.279 205	25.04467
m 3	32.327 706	3.153 827	21.04467
m 4	26.592 583	1.385 066	17.04467
m 5	20.757 725	-0.020 087	13.04467
m 6	14.153 202	-1.155 218	9.04467
m 7	7.495 283	-1.917 109	5.04467
m 8	1.500 486	-2.204 032	1.04467
m 9	-4.500 518	-2.113 973	-2.95533
m 10	-10.484 013	-1.647 286	-6.95533

LAYOUT FOR THE NEUTRINO SEARCH
WITH THE HEAVY LIQUID BUBBLE CHAMBER

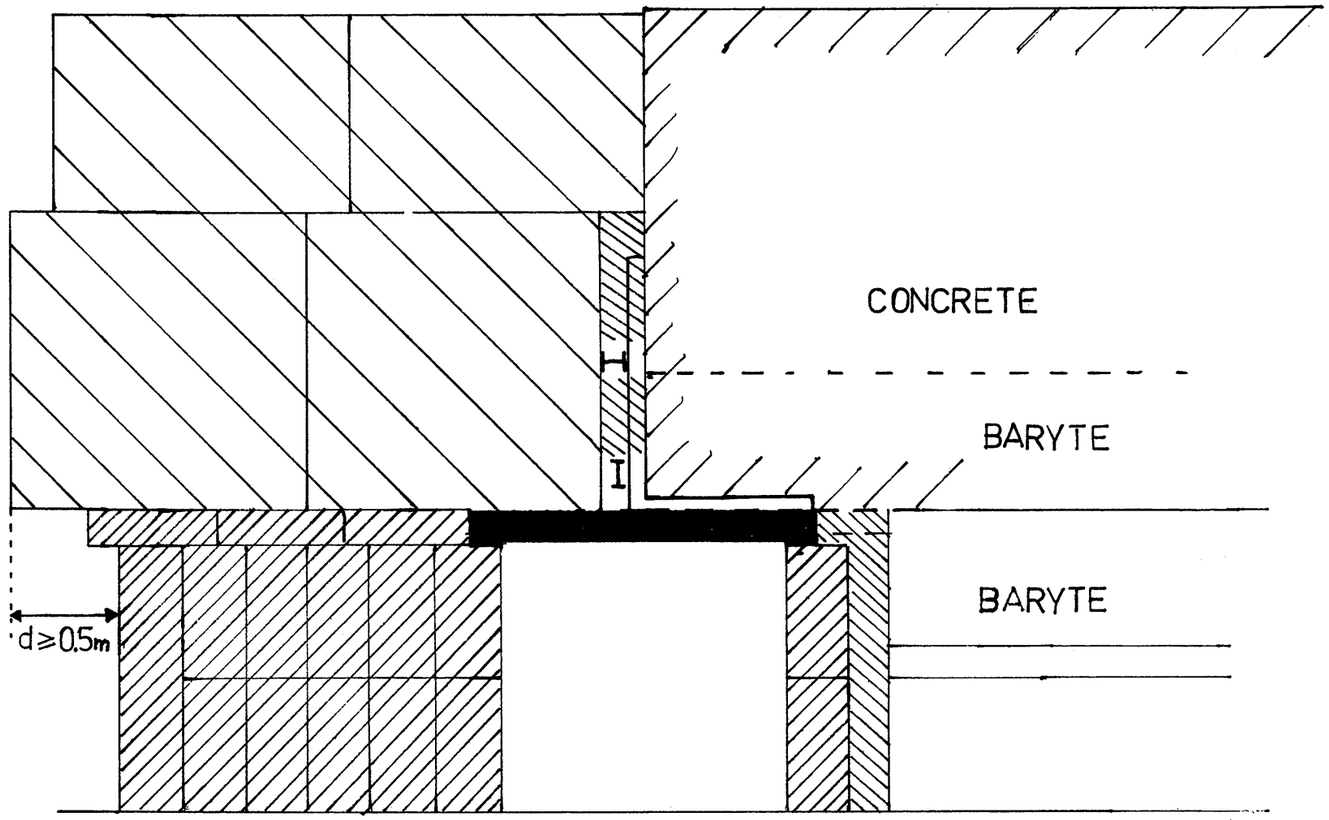
HALL SUD

1:100

CERN-PS
GENÈVE

Fig.1

SIS. R/2070



Steel

Baryte

Concrete

Small baryte blocks

Existing shielding

Item Pos.		No. req. Nb. de p.	Descriptions	Material Matière	Pattern Modèle	Observations
1	11					
2	12					
3	13	III II I	SECTION BB of Fig.1 THROUGH DECAY TUNNEL		Scale Echelle	CERN- GENÈVE
4	14					
5	15					
6	16					
7	17		Modifications		Signatures	
8	18				3/11/60	
9	19					
10	20					

Fig. 2

SIS. R/2068

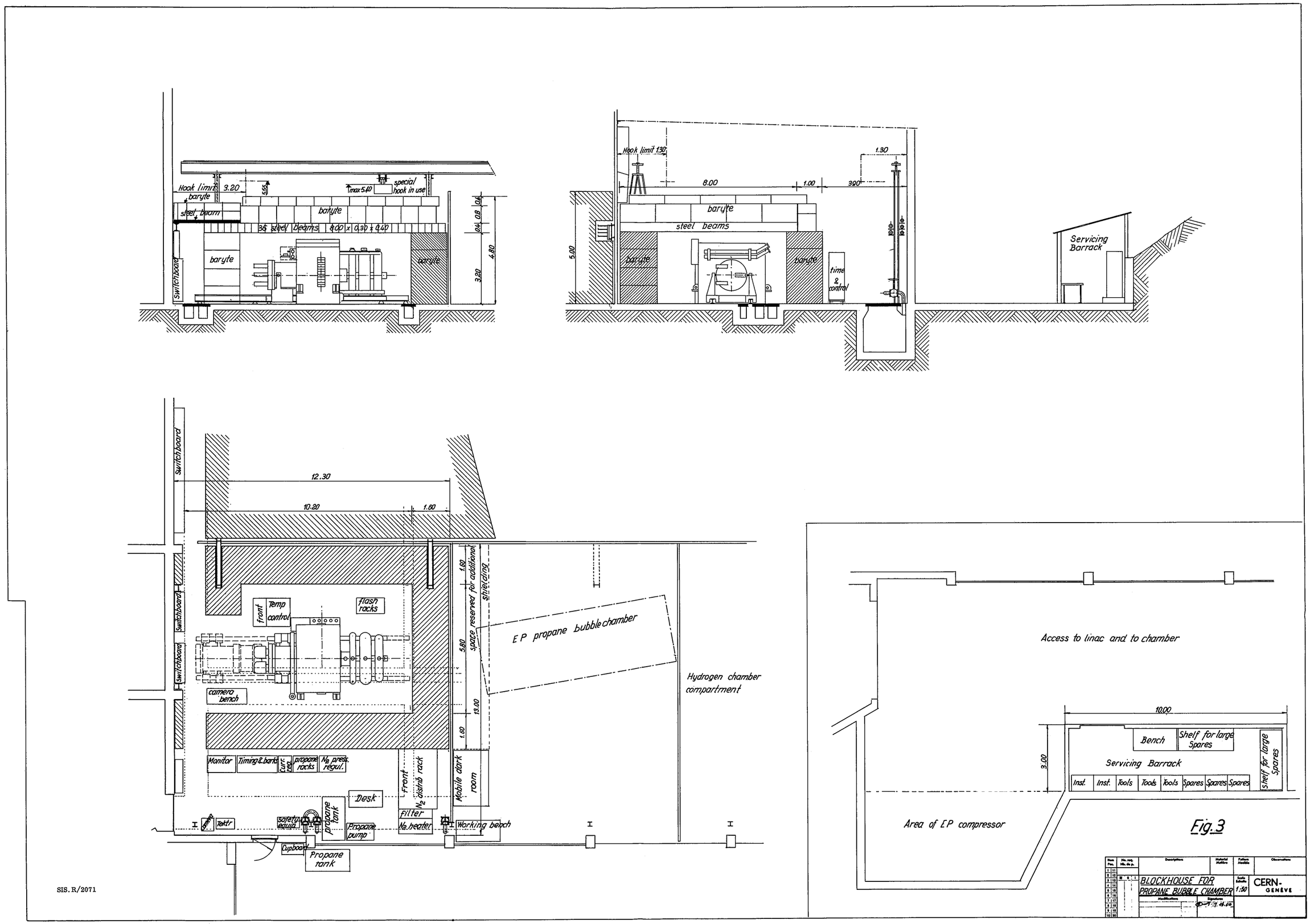
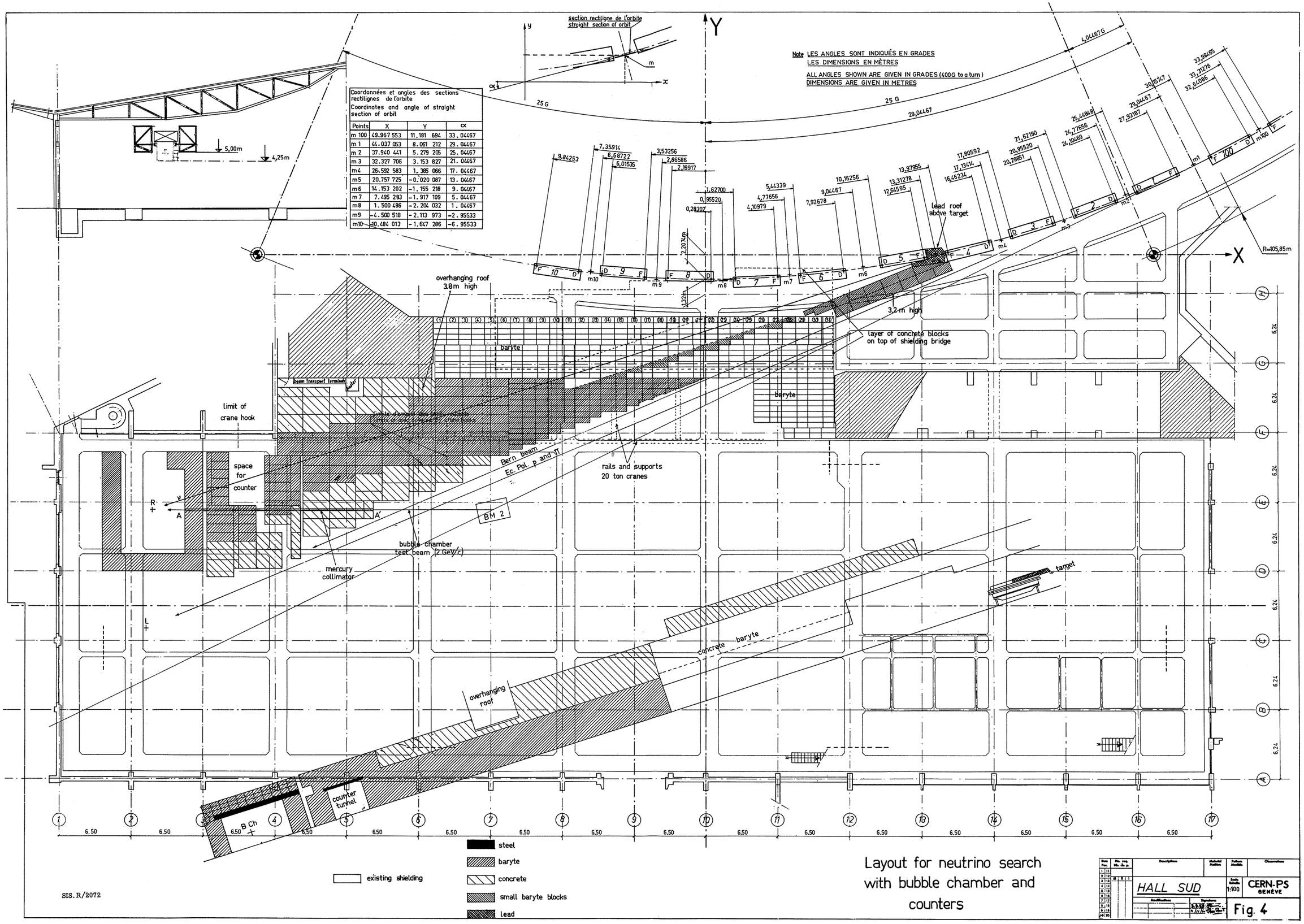


Fig.3

SIS.R/2071



Coordonnées et angles des sections rectilignes de l'orbite
Coordinates and angle of straight section of orbit

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Layout for neutrino search with bubble chamber and counters