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EXPERIMENTAL AREA DESIGN WITH MINIMAL MODULAR SHIELDING

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This note outlines the principal features of an experimental area designed not to require the use of uranium shielding to absorb muons. It is hoped that an appreciable amount of money may be saved by such a design.

The new design has two major features. One is that nearly all the muon shielding is to be obtained with earth rather than modular shielding. The other is an explicit separation of the experimental area into a target area (with subordinate access and utility areas), secondary beam transport tunnels, and experimental areas at the end of a secondary beam.

In order to help achieve the first objective, a secondary feature, of somewhat less critical nature than the two major features, is proposed: the use of much less dispersion than is customary in present designs, of the secondary products from the target; we diminish the integrated magnetic field traversed by the secondaries. This feature is of considerable assistance in achieving the first objective - the substitution of earth for the modular shielding.

The low density of earth shielding (1.8) implies that about 250 meters of earth are necessary in the forward direction to reduce the muon intensity to acceptable radiation dosage levels, for a 200 GeV beam; for 400 GeV, twice as much is required. This sets a premium on putting the target area underground, so that the required shielding will be automatically present. However, the use of a beam at or near grade level is not ruled out. The flexibility of running secondary beams above ground rather than below, and the relative cheapness of moving large volumes of earth favor this alternative; it has not as yet been studied.

Figs. 1 and 2 show a sketch of the target-experimental area system, as it might appear with a particular array of secondary beams; for the sake of definiteness the secondary beams shown are a 100 GeV/c positive beam, and two variable energy (25-50 GeV/c) positive and negative beams of high intensity. An additional negative beam of high momentum can be added if desired.

For the purposes of shielding design, the muon angular distribution at production is approximated by that of the pions; this is a rather conservative position, since the muon spectrum is in fact appreciably lower in energy. The highest energy muons (those above, say, 60 GeV/c) are contained almost entirely within a 1-degree cone. Their angular distribution is independent of proton beam energy, so that the shielding need only be augmented in the forward direction when the proton energy is raised.

Downstream of the target, a magnet provides dispersion of the secondaries; the dispersion is needed to separate different momenta and to make secondary beams using particles produced at small angles, down to 0 degrees. The laboratory angular distribution of the pions and muons is primarily determined by this dispersion. Only a small magnet (10 kg-meters) is needed to double the initially small transverse particle momentum;

most previous designs provide deflections 10 to 20 times this large. The resulting muon distribution is thereby fanned out into a bilobed pattern of separated positive and negative particles. (The residual undeflected strongly interacting neutrals are readily absorbable.) The longest range muons are still most nearly forward, but the positive and negative peaks may now be separated by as much as two or three degrees, with some long-range muons (60 GeV/c) at angles up to 7°. This has the effect of making a very large downstream area uninhabitable unless these muons can be absorbed, which in turn requires large amounts of modular shielding in conventional schemes (i. e., LRL target areas, CERN area I).

Three new possibilities present themselves for solving the problem of getting the secondary beams out of the intense muon field, so that detecting equipment may be set up free of the primary muon flux. (That portion of the muon flux at the detection equipment, due to decay in flight of the focused secondary beam particles, presents a problem which cannot be avoided and is independent of how the secondary beam is generated.) The first method (No. 2 in Table 1, which includes as No. 1 the conventional one) confines the muon flux to a small angle by limiting the dispersion after the target, and provides sufficient further magnetic deflection in the same plane to bring the secondary beams out of the intense muon field.

A second method deflects the secondary beams out of the plane in which the secondaries are dispersed: then the deflection angles required are small, needing only to exceed the production angles. Normally the initial dispersion is carried out in the horizontal plane (3a in Table 1), so that obvious deflection of the experimental beams would be upward, thus bringing them into the open where experimental areas can be built without excavating. Fig. 3 shows a sketch of this possibility. This scheme becomes even more attractive if the incoming protons are pitched downward a degree or so, to reduce further the upward muon flux.

A possible alternative (3b) - at first sight not too attractive since it deflects some muons upward - might be to disperse in the vertical plane, and deflect the experimental beams horizontally. In this case the initial downward pitch of the proton beam could well be 2 to 5°.

Alternative 3 has not been extensively examined. Successive magnetic deflection in two perpendicular planes complicates the calculation of trajectories somewhat, especially for beams intended to carry a wide momentum range, but it seems clear that there are cases in which it need not introduce serious difficulties.

A third method, No. 4 in the table, is really a special case of No. 2. It refers to those cases in which the secondary beam will be over 250 meters long in any case. Then no special deflection is needed to remove it from the muon field, and we can dispense with the modular shielding independent of whether we use large or small dispersion at the target. This scheme is especially suited to the production of a neutrino-muon beam or a high-intensity high-energy beam.

A more detailed sketch of the target area for method 2 is shown in Fig. 4. This area must contain the target (or targets), the dispersion magnets, dense hadronic shielding near the target, and the initial elements of the secondary beam transport. In addition means for handling the shielding and transport elements within the area, and of removing them from the area, are necessary. A small and inexpensive overhead crane can take care of the former; the latter can be taken care of either by access along the proton beam feed tunnel, a special access tunnel, or with removable roof shielding. It was originally proposed to have the first and last of these; it now seems preferable, on further reflection, either to widen the incoming proton beam tunnel as far back as the next access penetration, or to provide a special access tunnel combined with a utility area for bringing in and out heavy or radioactive equipment. Such an access tunnel is sketched in Fig. 1.

The secondary beam tunnels must extend outside the primary decay muon field, beyond the area in which transport is inaccessible when the proton beam is operating but the particular secondary beam line is shut down. There is considerable question as to whether the secondary beams should be built in complete well-equipped tunnels, stripped tunnels with minimal facilities, or mere pipelines through the earth between magnet stations. In addition, there is the question referred to above concerning which plane to deflect the tunnels in. Since a deflection of only a few degrees is needed, a maximum tunnel grade of five to ten percent should be adequate for most beams. The expenditures for the tunnels for the experimental beams will reflect the judgment of how important flexibility of beam design is for each beam; beams expected to remain unchanged for long periods need less flexibility.

Beyond the region where the primary muon flux presents a health hazard, the secondary beam shielding requirement is determined by the flux of particles being carried, and only for the most intense beams exceeds a meter of iron equivalent (see R. Thomas, ECFA Vol 2, p. 305). We defer further consideration of the beam transport tunnels, for the present.

Contamination of Secondary Beams by Muons

It has been suggested that one of the purposes of the dense modular muon shielding in the conventional high-density all-purpose experimental area is to keep secondary beams from being contaminated by muons that wander into it and are captured into the beam. This is not quite as improbable for muons as it would be for hadrons, since a collision with a magnet yoke or collimator jaw doesn't bother a high-energy muon very much; the passage through the yoke, in fact, may deflect it back into the beam. Inside the main ring, muons originating from pions produced in a septum may be trapped in the ring for some time before escaping. However, the secondary beams are far leakier than the ring - they have fewer components per unit length - and the phase space density of the muons is a few orders of magnitude lower than that of the pions. This follows not only from the small fraction of pions that decay near the target, but also the extended character of the decay source. Consequently, unless a detailed study of trajectories indicates otherwise, it seems highly unlikely that such muons can exceed in number the fraction that appear in present-day beams - about one to five percent, as a rule, most of which originate close to the target.

Secondary Beam Areas

The far end of the secondary beam demands study to determine how to handle the muon contamination from the pion decay, how many beams of different energy can or should be brought into the same area, and how they should be branched before entry to permit the simultaneous installation of two alternate experiments on the floor for each beam.

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This discussion has benefited considerably from the comments of many others, especially during the informal meetings of the week of August 21, 1967.

TABLE 1

Solutions to the Muon Shielding Problem

	Scheme	Muon Shielding	Dispersion	Further Beam Deflection
1.	LRL, CERN-I	Modular (uranium)	large, horizontal	small
2.	Fig. 1	Earth	small, horizontal	large, horizontal
3a.	Not Examined	Earth	large, horizontal	small, vertical
3b.	In Detail	Earth	moderate, vertical	small, horizontal
4.		Earth	large or small	small

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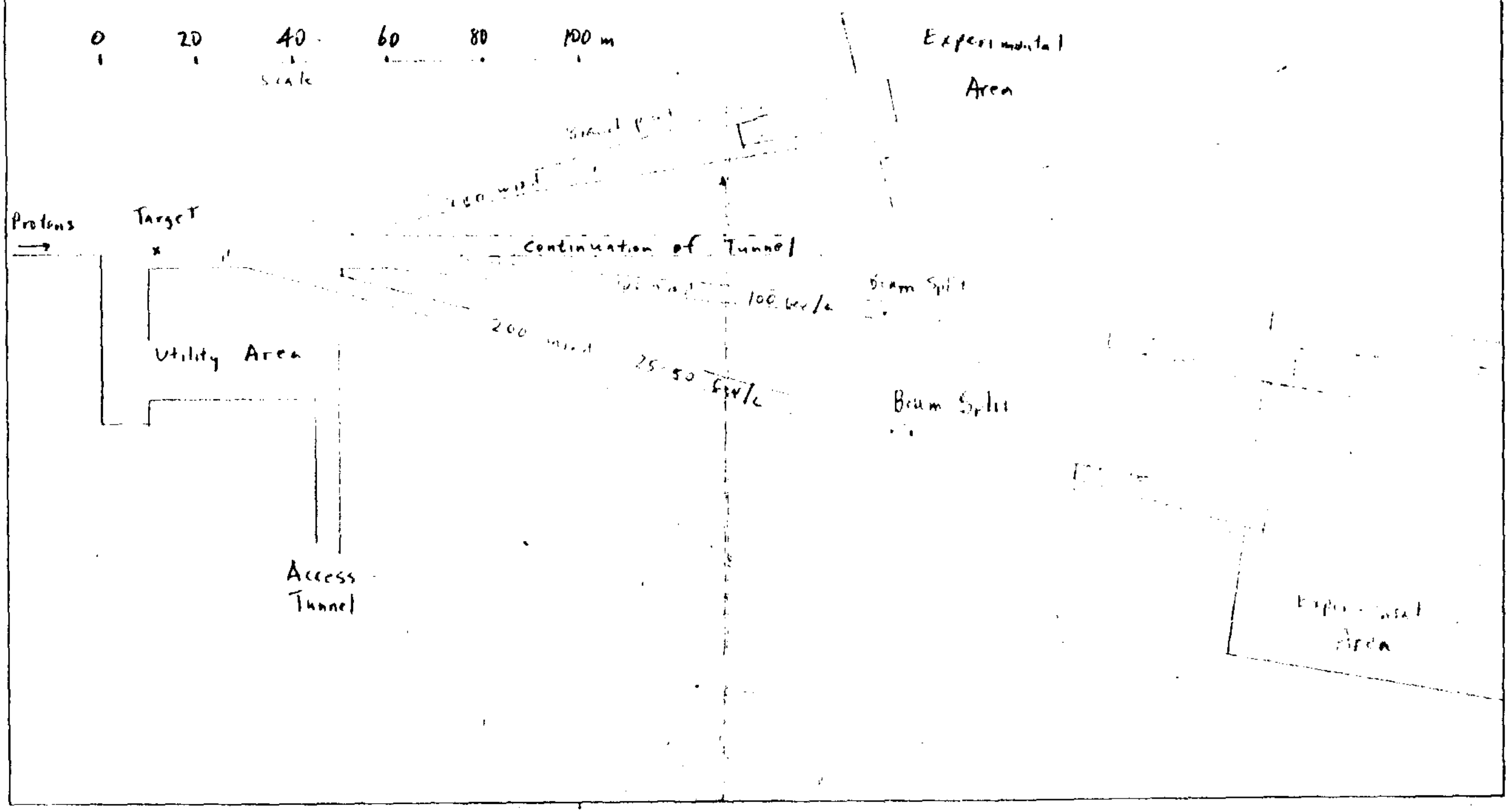
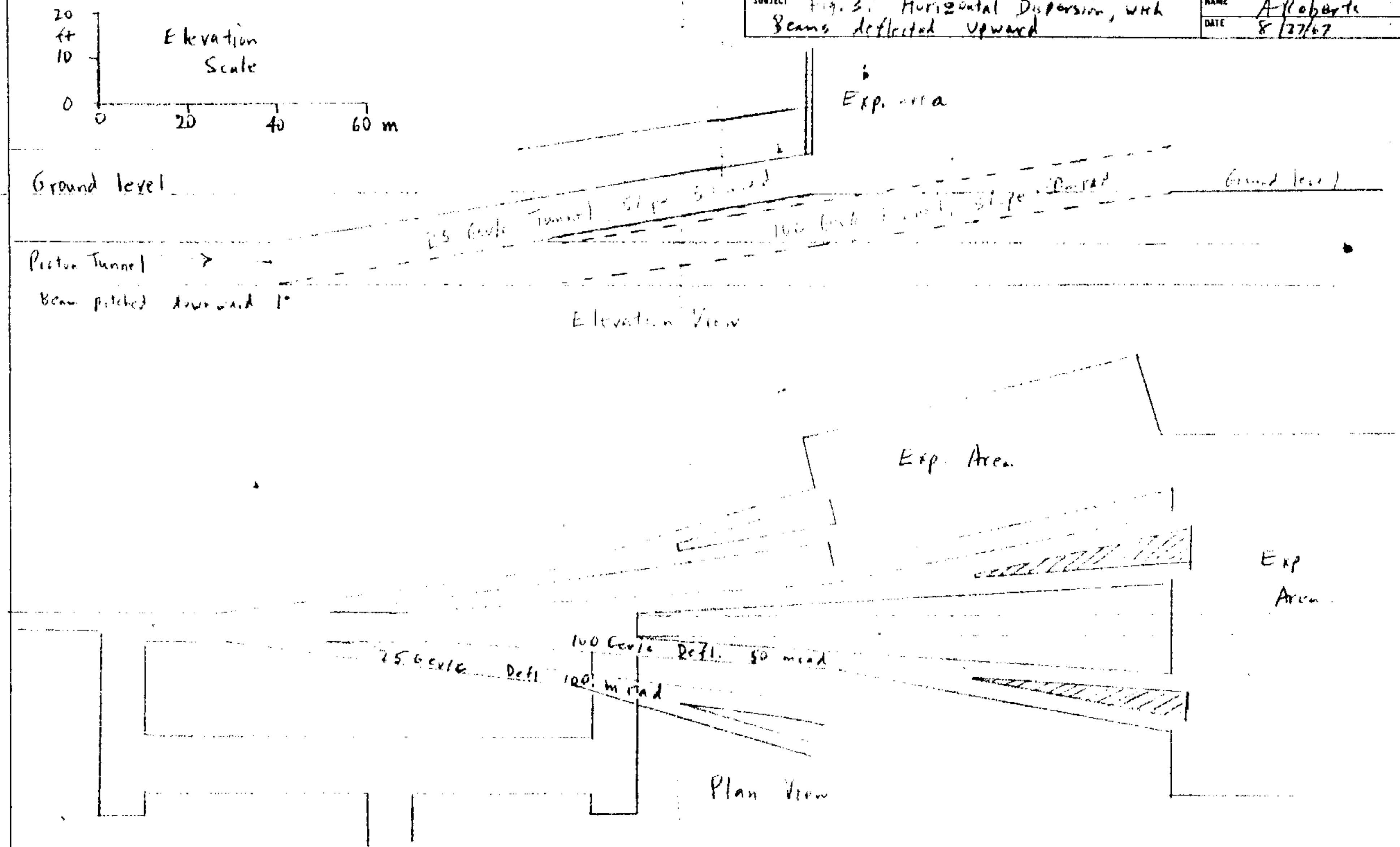
ENGINEERING NOTES

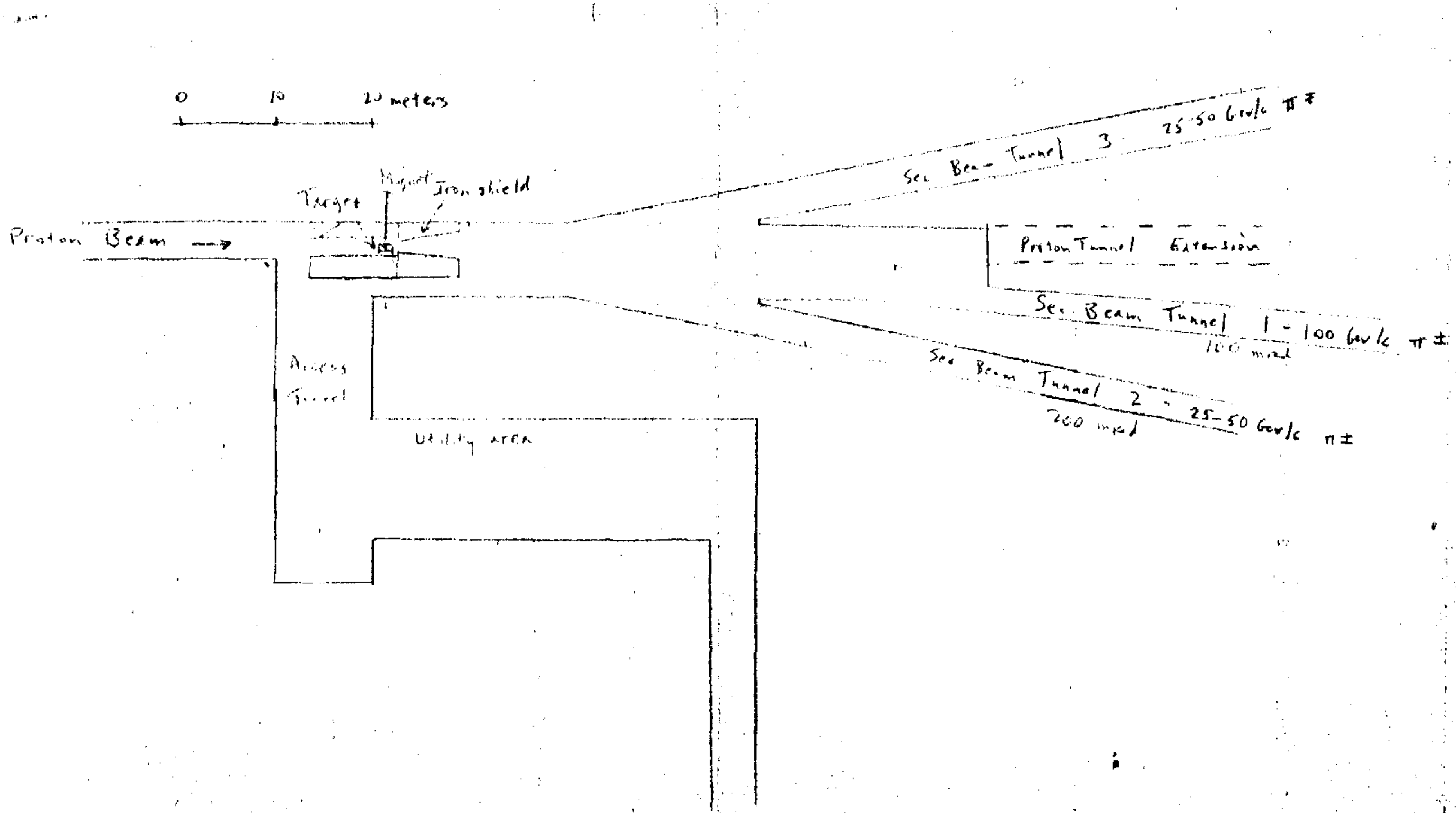
SUBJECT	PROJECT	DIVISION	SHEET OF
Fig. 1	NAME A Roberts		
	DATE 8/27/67		



ARGONNE NATIONAL LABORATORY ENGINEERING NOTES	PROJECT	DIVISION	SHEET OF
SUBJECT Fig. 3. Horizontal Dispersion, with Beams deflected upward	NAME A Roberts		
	DATE 8/27/67		



ARGONNE NATIONAL LABORATORY ENGINEERING NOTES	PROJECT	DIVISION	SHEET OF
SUBJECT Fig 2. Target Bldg. Detail	NAME A Roberts		
	DATE 8/27/67		



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