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Appendix G

Civil Construction

The GlueX experiment will reside in a new experimental hall (Hall D) located at the end of a new beamline off the stub at the east end of the North Linac. Figure G.1 gives a schematic view of the accelerator site and the proposed location for Hall D. The elevation of the beamline is 1.24 m below the nominal grade level. This height balances considerations of the beamline optics, radiation shielding issues, and civil construction cost. The figure in the foldout shows the plan and elevation views for the Hall D beamline and associated buildings.

Civil construction includes breaking through the accelerator stub, tunnel construction, beam transport system and instrumentation. The above ground facilities include the tagger building, Hall D, service buildings, beam dumps, control room, roads, and parking area. Basic infrastructure for all utilities is provided for all buildings [1].

We have had numerous meetings with JLab civil construction, accelerator, and RadCon staff, and conclude that there are no serious civil construction issues. The main problem is to minimize cost while satisfying GlueX requirements. In particular, the beamline and buildings will fit on DOE/SURA land, building construction should be straightforward, and RadCon problems can be handled by standard techniques. A formal agreement to use a portion of land owned by SURA for the GlueX project is under consideration.

G.1 General requirements

Requirements and specifications assuming a maximum electron beam energy of 12 GeV are given in Table G.1 and below:

- Single electron energy available for the D line

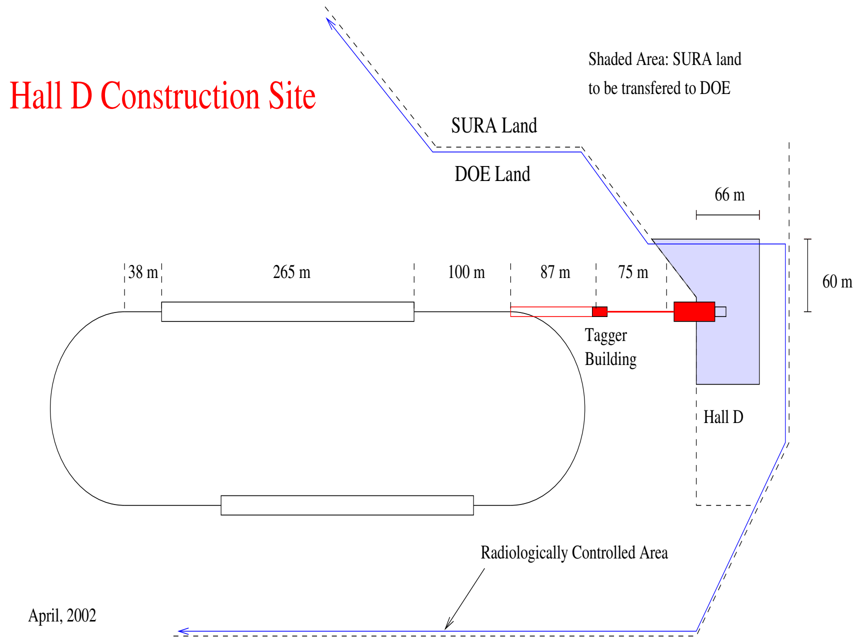


Figure G.1: An overall view of the accelerator site and HALL D.

Parameter	Operating Value	Design Goal
Max Electron Current	3 μA	5 μA
Min Electron Current	$\sim$0.0001 μA	0.0001 μA
Electron Energy	12 GeV	12 GeV
Power	36 KW	60 KW
Photon Power (Collimator)	7 W	10 W
Photon Power (Detector)	1 W	1.5 W

Table G.1: Beam parameters for a 12 GeV electron beam.

- HALL D is designed for a photon beam only (i.e. no primary electrons into HALL D)
- Civil construction compatible with 24 GeV beam (e.g. 80 m bend radius)
- Accelerator tangency point to radiator = 87 m
- Radiator to collimator distance = 75 m
- Tagger building = 7 m x 15 m x 3.5 m (height). Nominal beam height above tagger floor = 1.5 m. The beam is nominally 4.5 m from the south

wall and 2.5 m from the north tagger wall.

- Housing for sideways electron beam dump = 3 m x 5 m x 3 m (height)
- Detector building = 17 m x 30 m x 9 m (clear hook height). The nominal beam height above the Hall D floor = $3.5 \pm 0.3\,m$, 10 m from the south wall, and 7 m from the north wall in Hall D.
- The collimator alcove is 4.5 m x 12 m x 3 m (height). The beam is nominally 1.5 m above the floor and 2 m from the north wall.
- Permissible building settlements: 1 *inch* initial; 2 *inches* max over lifetime

G.1.1 Compatibility with future upgrades

The allocation of space for the beamline instrumentation and layout of the site is designed such that an accelerator upgrade to 24 GeV would be possible using proposed buildings and tunnels. We assume that during 12 GeV operation Hall D would only receive 5.5-pass beam. For 24 GeV operation Hall D would receive 4.5, 3.5 or 2.5-pass beam; the number of passes will be switched at most annually. This implies that conditioning for the Hall D beam cannot start before the tangency point and no recombiner area is required. For 24 GeV operation, an east two-way RF separator would be used to extract the beam; the configuration could be changed during long shutdowns by relocating extraction and transport elements.

G.2 Personnel protection

The Jlab Beam Containment Policy requires that personnel be protected from accidental beam loss by at least three independent devices built using at least two different technologies.

G.2.1 Failure scenarios

The following failure scenarios were identified:

- Failure of vertical beam transport, shooting electron beam into the sky.
- Poor tuning or steering of electron beam.
- Excessive current in electron beamline.

- Tagger magnet failure, directing electrons down the photon line.
- Excessive photon flux (resulting from obstructions in the electron beamline, poor vacuum, etc).

G.2.2 Beam containment proposal

In the following we list the active and passive safety devices that assure the primary electron beam reaches the diamond radiator and the electron dump. We believe these devices satisfy the Laboratory beam containment rules as well as the SLAC beam containment rules, where there are currently two "above ground" primary electron beams in operation. See Ref. [2].

Electron beam on diamond radiator

1. There should be a beam current monitor near the exit from the linac which will turn off the beam if the current exceeds the Hall D requirement.
2. The bend string, which brings the beam up from the accelerator and back to horizontal, must be in series on the same power supply.
3. The bend string power supply should be equipped with a "meter relay" which shuts off the primary beam if the supply current varies by $\pm 10\%$ from its desired value.
4. Preceding the diamond radiator there should be a small aperture protection collimator with a burn-through monitor and a beam-loss detector, such as an ion chamber, which will shut off the beam if it hits the protection collimator.

Electron beam on the dump

1. There should be a meter relay on the tagger magnet power supply to turn off the beam if the supply current varies by more than $\pm 10\%$ from its desired value.
2. There should be a beam current monitor set to a low threshold in the photon beam line just downstream from the tagger magnet which will shut off the primary beam if it detects a charged beam in the photon line.

3. Following the current monitor there should be a permanent magnet to bend a charged beam downward.

4. There should be small aperture protection collimators with burn-through-monitors on either side of the permanent magnet with ion chambers or other type of beam loss detectors near the protection collimators.

5. There should be a beam current monitor just upstream of the 60 KW electron dump. This current reading can be compared to the current reading at the exit of the accelerator and shut off the beam if the readings differ by more than a few percent.

G.3 Environmental and radiation concerns

The civil construction includes shielding for all buildings which is sized based on preliminary, but conservative, estimates of expected radiation doses. Guidance was provided by the original calculations by Lewis Keller, who has served as a consultant on this project. The Jlab RadCon group has refined his estimates using GEANT based simulations and a realistic geometry for the buildings.

G.3.1 Site dose limits

On–Site The design goal at Jefferson Lab for a controlled area is 100 mrem/yr which may include occupancy as a factor and is based on guidelines from the Jefferson Lab RadCon Manual. Based on exposures of less than 2000 hours/yr, this sets an average dose limit of less than 50 μrem/hour. There is also an instantaneous accident dose rate limit which is identified in the Jefferson Lab Beam Containment Policy as 15 rem/hour based on maximum credible beam loss conditions.

Site boundary The integrated dose limit at any point on the site boundary is 10 mrem/yr, or 2 μrem/hour using an occupancy period of 5000 hours/yr.

G.3.2 Beam on radiator

For the purpose of estimating dose rates, RadCon assumes that losses along the transport line are of order 0.1%. Following the vertical bends, two burn-through monitors with small apertures preceding the radiator are needed. In addition there should be a 1-2 m steel wall downstream from the last vertical bend, as in the beam lines to existing halls. The surface is shielded from the tunnel by 4 m of earth. For comparison, we note that a similar vertical string configuration for the Hall B beamline is shielded by 2.3 m of earth.

G.3.3 Tagger building

Jlab rules require that the instantaneous dose rate in occupied areas (outside the building) during a beam accident be less than 15 R/hr, assuming the beam will be turned off in less than 1 second. Using a a safety factor of 10-15, it was determined that 4 m of earth was required for the shielding against photons and neutrons.

G.3.4 Tagger hodoscope

Assuming the dump is 60 m from the hodoscope elements and that there is a 5 cm vacuum pipe leading to the dump, the neutron rate coming backward from the dump is 3×10^6/s, and the photon rate is 0.9×10^8/s for a 60 KW beam on the dump.

G.3.5 Electron beam dump

The electron beam dump proper will be based on a design similar to the existing BSY 120 kW dump[1] at Jlab. Beam dumps with similar characteristics are in use at SLAC [3]. We have extensive operational experience with the BSY dump and detailed calculations [4] of neutron production and ground water activation for this geometry. This dump is designed so that all the primary beam energy is dumped in solid metal. The closed water circuit for cooling sees only thermal energy, not beam energy, and there is no hydrogen generation. The dump will require regular service, which can generally be performed from outside the building itself. The absorption of longitudinal showers, including muons, will be accomplished with the beam dump proper, aided by an additional 10 m of Fe downstream to insure containment. JLab requires that the dose rate must be less than 50 μrem/hour in controlled areas. Therefore, the lateral containment of photons and neutrons resulting from the 60 KW beam, also requires 1 m of steel and 5 to 6 m of earth on the top and sides of the building.

[1] An identical dump is available, which is located in the north linac "stub" and was used in commissioning days, but must be removed during the construction of the Hall D transport tunnel. It has a closed circuit water system attached, along with steel shielding for neutrons.

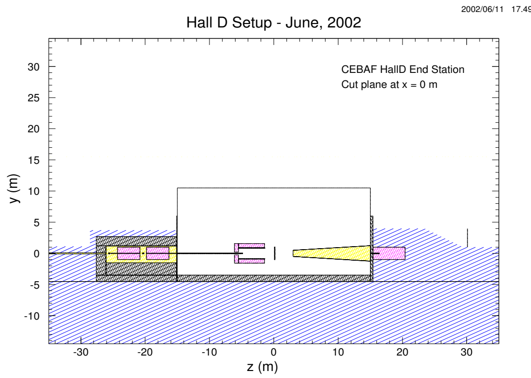


Figure G.2: Side view of the Hall D building and shielding. The upstream enclosure contains the photon collimator. The photon beam dump is downstream (right).

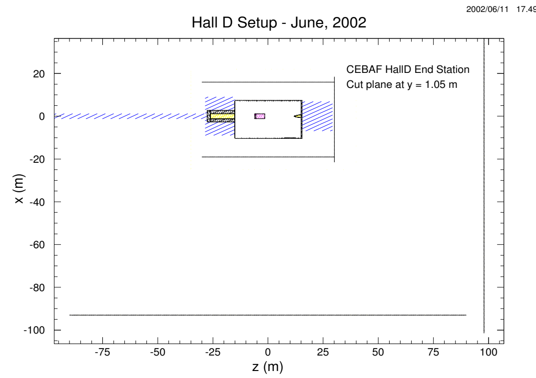


Figure G.3: Top view of shielding modeled in the simulations. Also shown are the scoring planes where radiation doses were recorded.

G.3.6 Collimator enclosure

Assuming a dose limit of 50 μrem/hour outside the building, a 10 W photon beam, and a safety factor of 10, 1.0 m of steel is needed on the top and sides of the collimators for high-energy neutrons, and 1.7 m of earth or concrete is needed in the backward direction for the giant-resonance neutrons. The design and specifications of the photon beam are given in Chapter 4.

G.3.7 Detector building

The calculations of radiation dose for the Hall D building and site boundary were modeled with a GEANT code used by the JLab RadCon group. The program has been tested favorably against data in existing experimental areas. The photon beam on target was generated using a 1/E spectrum for the incoherent flux plus a coherent spectrum representative of a typical crystal radiator. The total power in the beam was 1.5 W, which corresponds to a tagged rate of 10^8 photons/s. The upstream collimator enclosure, where 10 W of the beam is deposited, is assumed to have sufficient shielding so that it does not contribute to the resulting dose rates. The model for the building and shielding are shown in Figs. G.2-G.5.

The model for the Hall D building has concrete walls of different thickness from 10 cm upstream to 40 cm in the forward direction. The height of the walls is 5 m above the local grade level. Above the wall, we use a "tin box"

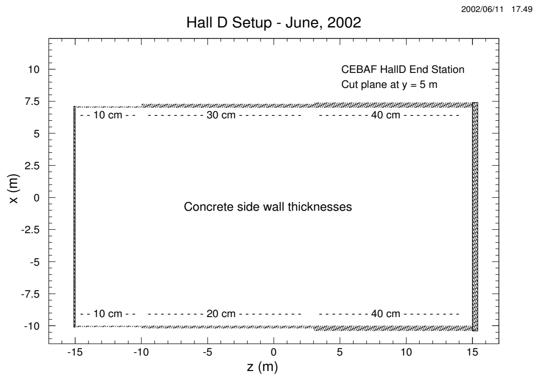


Figure G.4: Top view of the HALL D building showing the wall thickness used in the simulation.

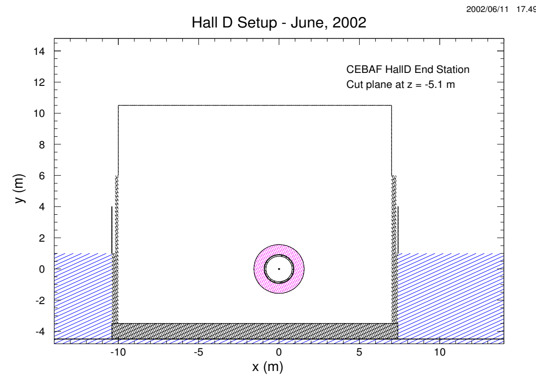


Figure G.5: Cross section of the HALL D building with the magnet.

construction of thin steel (0.6 *mm* thick walls; 0.8 *mm* thick roof). The target is 30 *cm* of liquid H_2, positioned inside the iron cylinder representing the coils and yoke, and the layers of lead representing the lead glass calorimeter (barrel portion, and forward portion). The photon beamline downstream of the detector is filled with He. The photon dump is 10 *cm* diameter and 1 *m* long hole in the dump iron. The truck ramp provides access to the building through a thin door. During accelerator operation, a fenced area is required 10 *m* from the truck ramp entrance.

The calculated radiation doses are shown in Fig. G.6 for various locations around the building. In all cases the dose rates are dominated by low energy neutrons which are not completely shielded. The estimated average dose rates are 10 μrem/hr in the Counting House, 20 μrem/hr in the parking lot, 5-10 μrem/hr 15 *m* from the building, and 0.5 μrem/hr at the site boundary.

The present solution appears to be acceptable both from the point of view of site boundary accumulated dose, and from the point of view of the dose rates around the building. The only additional safety measures would be the requirement to restrict access to the truck ramp area (if the entrance door is thin), and some restrictions on performing elevation work close to the Hall (roof of the counting house, light poles/fixtures, etc.)

G.3.8 Photon beam dump

The photon beam dump is required to absorb up to 1.5 W of photons which survive collimation and are used for experiments in HALL D. The photon beam

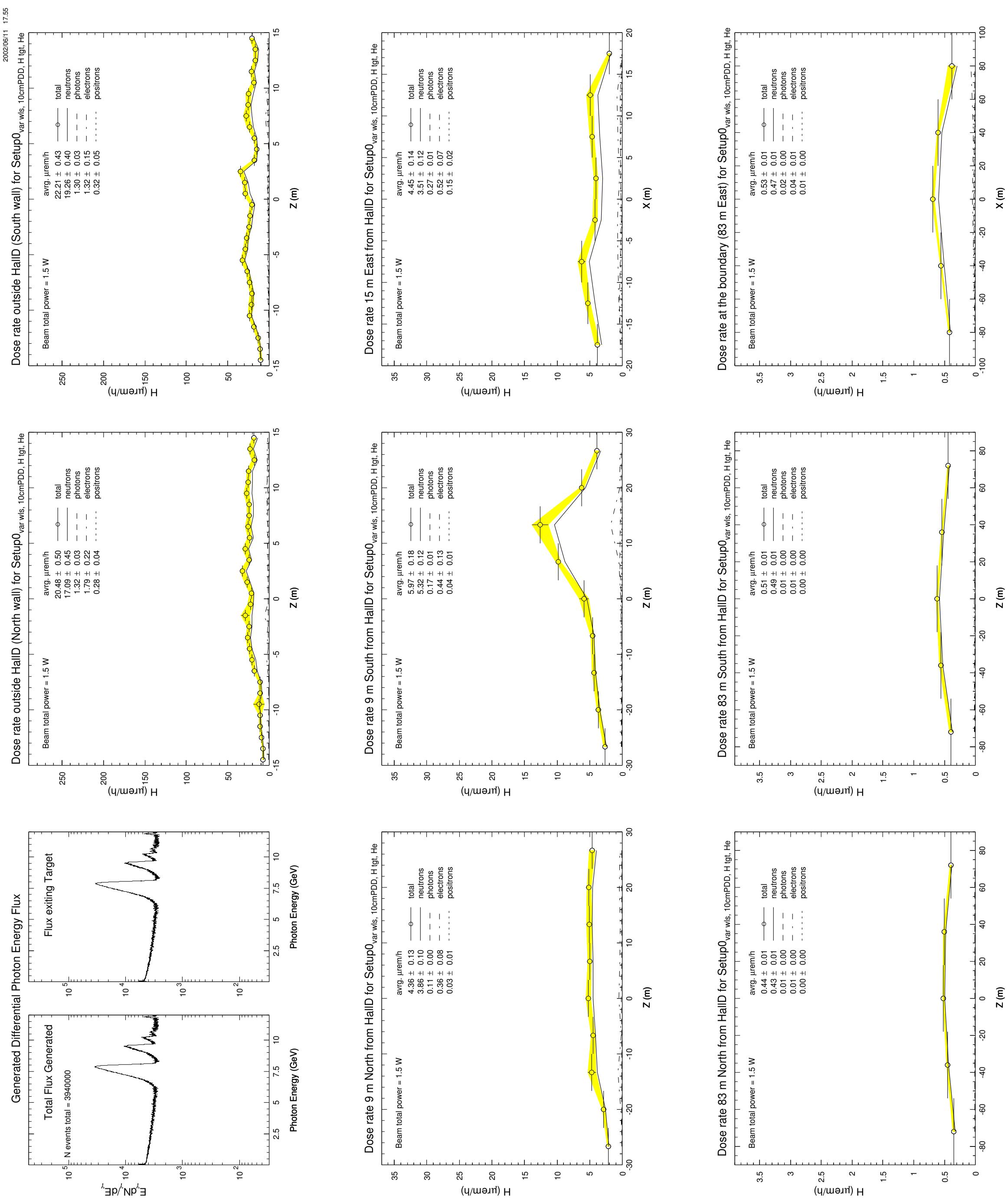


Figure G.6: Dose rates predicted by GEANT simulation code for various locations surrounding Hall D.

must be transmitted to the interior of the dump in order to minimize the flux of secondaries scattering back into HALL D. A few meters of steel is adequate to contain the residual muon production, covered by earth to stop neutrons. Most of the muons produced in the collimation enclosure are absorbed before entering HALL D[5, 6].

G.3.9 Ground water activation

Based on the present design, there are no concerns about surface water, ground water, or soil activation in the vicinity of the end station itself. Any concerns for groundwater and soil activation are limited to the beam transport line up to and including the structures containing the photon tagger assembly and the electron beam dump. Procedures in place for current operation will be used to address these.

G.4 Geotechnical analysis

Engineering Consulting Services, Ltd. has completed a subsurface exploration and geotechnical analysis to understand the foundation conditions for building construction for the Hall D site on the east end of the accelerator. Details of their findings can be found in their report [7]. We briefly summarize their work and review their conclusions which are of direct interest to the project.

Eleven borings were taken which covered the intended construction site. Each boring obtained nine samples down to a depth of 10 m. The samples were analyzed and classified according to the unified soil classification system. In Figure G.7 we have summarized the composition of the soil from the samples. They indicate that the soil above the Yorktown Formation, starting at depths of 5 to 6 m below grade, would not provide stable support for construction. The analysis shows that a mat foundation is an acceptable solution for the current design.

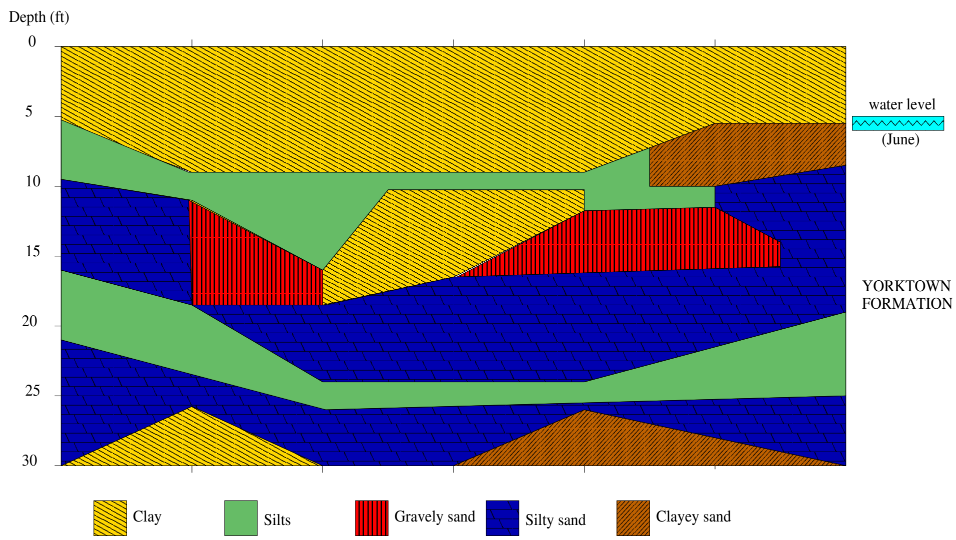
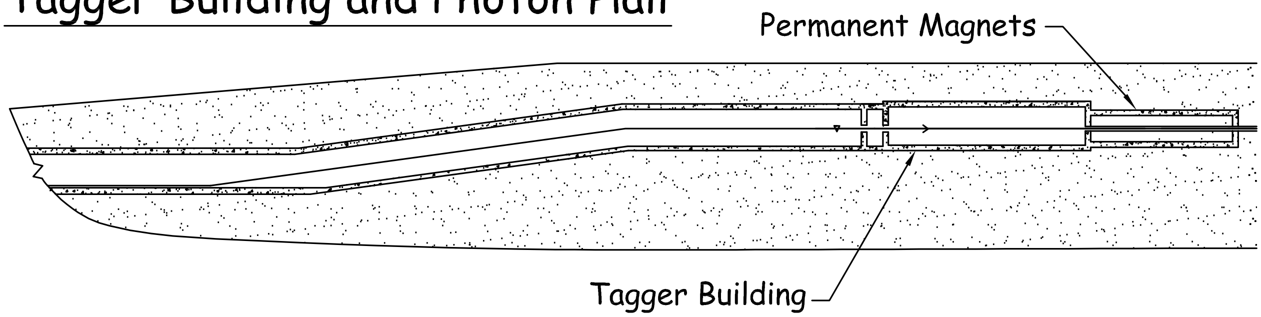
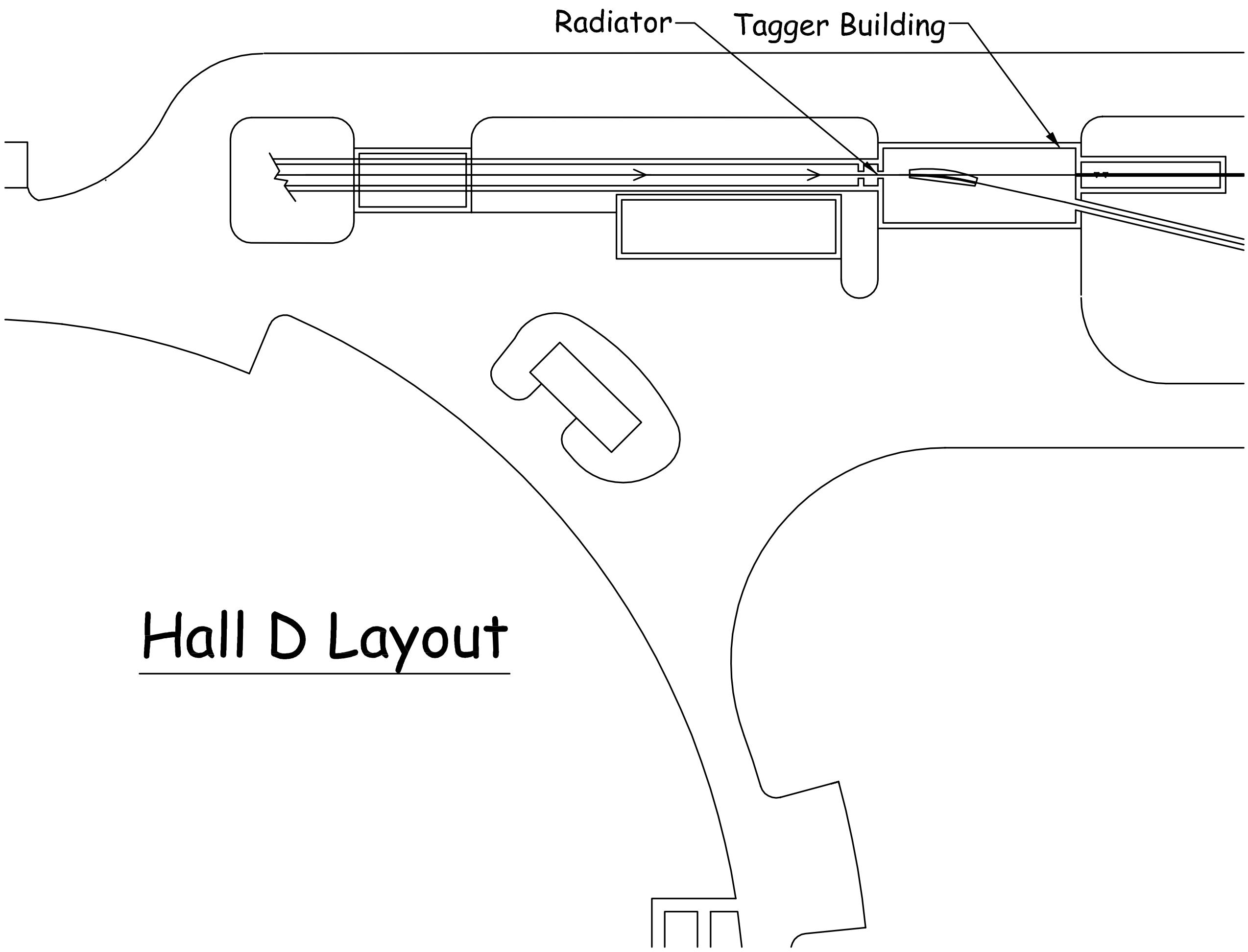
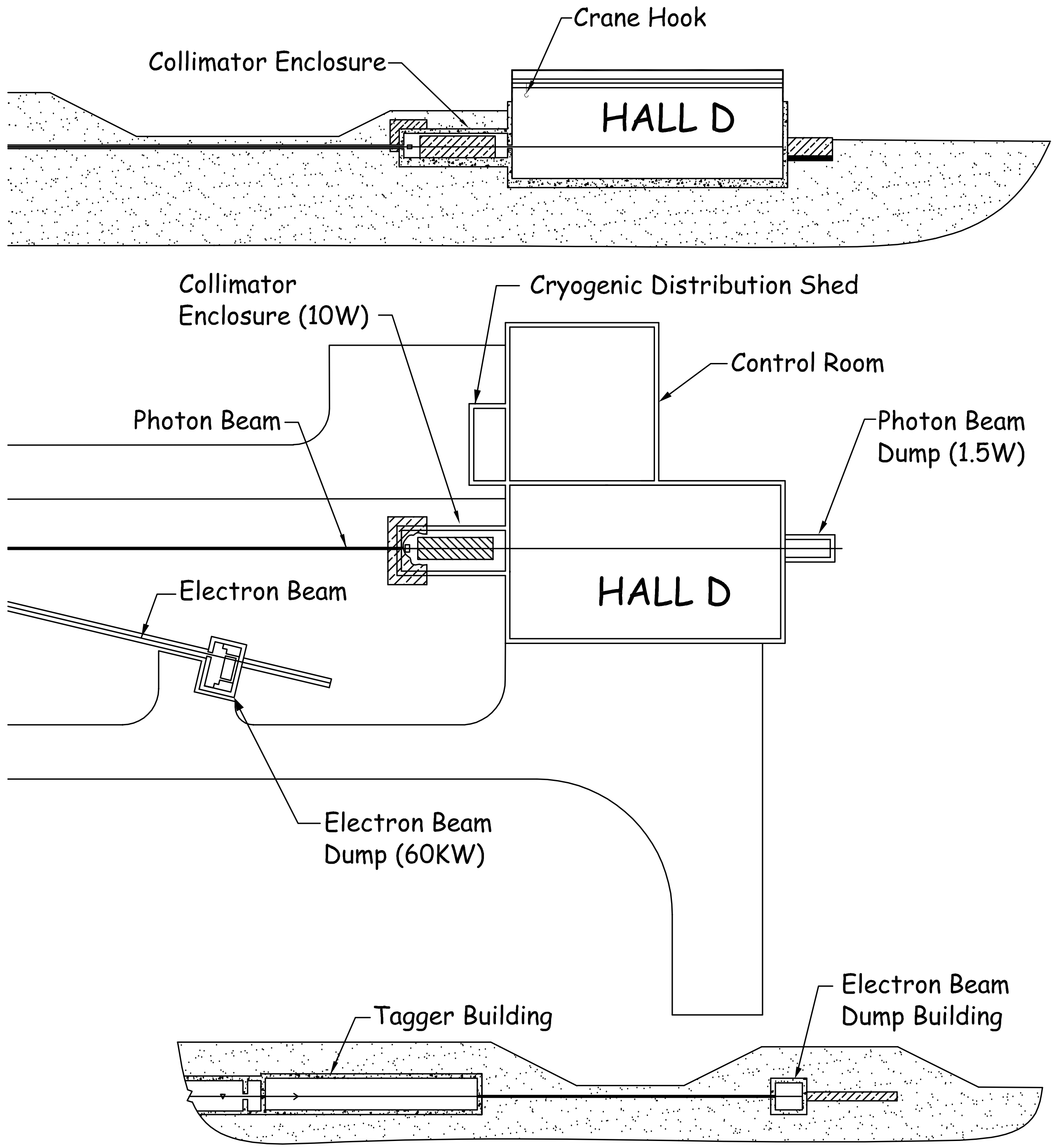


Figure G.7: Typical composition of soil under the HALL D construction site as a function of depth. Note that the horizontal dimension covers the distance from the accelerator to the building. The result of the geotechnical analysis shows that buildings at grade level will require support piles, driven approximately 15-20 m into the ground.

Tagger Building and Photon Hall







Tagger Building and Beam Dump

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Bibliography

[1] Drawings of the Hall D site can be found at http://www.jlab.org/Hall-D/civil/drawings.

[2] E.S. Smith L. Keller and E. Wolin. Beam containment proposal. Technical Report GlueX-doc-**32**, Jefferson Lab., 2000. http://portal.gluex.org/.

[3] A. McFarlane D.R. Walz and E. Lewandowski. Beam dumps, stoppers and faraday cups at the slc. In *Physics with 8+ GeV Photons Workshop*, 1989. IEEE Particle Accelerator Conference, Chicago, IL, March 20-23, 1989 (SLAC-PUB-4967).

[4] P. Degtiarenko. Neutron flux and ground water activation at bsy dump. Technical report, 1997. Intenal memo to R. May and G. Stapleton.

[5] Muon Background in a 1.0-TeV Linear Collider. Technical Report SLAC-PUB-6385, SLAC.

[6] L. Keller. Muon calculation results. Technical Report GlueX-doc-**33**, SLAC, 2000. http://portal.gluex.org/.

[7] Engineering Consulting Services Ltd. Report of subsurface exploration and geotechnical engineering analysis – hall d construction. Technical report, 1999.