INTERFACE CONTROL DOCUMENT

(REQUIREMENTS AND DIVISION OF RESPONSIBILITY)

ACCELERATOR AND EXPERIMENTAL SYSTEMS

ACCELERATOR AND HALL D

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ACRONYMS

AC	Alternating current
ALARA	As low as reasonably achievable
CHL	Central Helium Liquefier
DI	Deionized
DOE	Department of Energy
DX	Direct Expansion
EH&S	Environment, Health and Safety
FSD	Fast shut down system
fpm	Feet per minute
FPC	Fundamental Power Coupler
ft	Feet
HEPA	High-efficiency particulate air
HOM	Higher-Order Mode
Hz	Hertz
ICS	Integrated Control System
ID	Internal diameter
in	Inch(es)
JLab	Thomas Jefferson National Accelerator Facility
kV	kilovolt
kW	kilowatt
LCC	Life-cycle cost
Linac	Linear accelerator
LLRF	Low level radio frequency
MHz	Megahertz
NFPA	National Fire Protection Association
ODH	Oxygen Deficiency Hazard
PPS	Personnel Protection System
psf	Pounds per square foot
psi	Pounds per square inch
PLC	Programmable logic controller
rf/RF	Radio frequency
SBC	Standard Building Code
SF	Square feet
SRD	System requirements document
SRF	Superconducting Radio Frequency
TBD	To be determined
UL	Underwriters Laboratories
UPS	Uninterruptible power supply
WBS	Work Breakdown Structure

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ACCELERATOR AND HALL D

1. Intent of Document

The intent of this document is to provide the requirements and divisions of responsibility, beyond those defined in the "Interface Control Document for Accelerator and Hall D" [1], for the interfaces between Hall D and the Accelerator System Groups to also include Accelerator Operations.

2. System Roles

Accelerator System Groups:

The Accelerator Systems provide an electron beam of up to 12 GeV to the Hall D Tagger hall and 11 GeV to Halls A, B, and C. 12 GeV is the foreseen nominal energy for Hall D and it is understood that operating at a lower energy rapidly degrades the Hall D physics program. As the direction of the Hall D photon beam is determined by the direction of the electrons at the point where the photons are generated, the accelerator is also responsible for steering the Hall D photon beam.

Accelerator Systems is further divided into six systems: 1) SRF Cryomodules, 2)Beam Transport, 3) Linac RF and DC Power Systems, 4)Instrumentation, Controls, and Safety, 5) Extraction, and 6) Cryogenics [2].

Operations or Accelerator Operations, as defined in this document, refers to Accelerator Operations Division and/or Accelerator Operators and/or Accelerator System Groups.

Experimental Systems (Hall D):

Hall D is responsible for the systems which generate and monitor the Hall D polarized photon beam. Hall D will provide a diamond or an amorphous radiator which can be precisely positioned in the 12 GeV electron beam in the tagger hall. The interactions in the radiator generate bremsstrahlung photons which form the beam of photons to Hall D. The diamond or the amorphous radiator will be positioned using a precision goniometer. The overall setup of the electron and photon beam in relation to Hall D is shown in Figure 1. The momentum of the electrons which radiate the polarized photons is analyzed in the tagger spectrometer thereby measuring the energy of the radiated photons. The tagger magnet also directs the electrons which did not radiate photons towards the electron beam dump. The photon beam propagates from the tagger hall to the Hall D collimator cave extension. Here a collimation system selects the photons radiated at small angles, Which have a higher linear polarization. Additional sweeping magnets and clean-up collimation ensure that the collimation of the primary photon beam does not produce significant background for the experiments in Hall D. Downstream of the collimator cave the photon beam enters Hall D. Located in Hall D are a pair spectrometer to analyze the collimated beam, the Hall D experimental apparatus, and the photon beam dump at the far end of the hall. (The photon beam dump is not the responsibility of Hall D).

Details of the tagger hall containing most of the elements discussed below are shown in Figures 2 and 3.

3. System Requirements

Accelerator: The Accelerator Systems shall provide all equipment for delivery of beam of up to 12 GeV to the tagger hall, and the electron beam dump. The maximum beam current to the tagger hall is 3 μA and the minimum current will be 0.3 nA. Necessary safety devices shall be implemented to prevent the transport of any electron beam to Hall D. The characteristics of the electron beam required for Hall D are summarized in Table 1. [3] During the commissioning phase it is understood that the machine will not perform up to these specifications. A detailed commissioning plan will be developed to allow for the machine to optimize its performance and commission all its subsystems while the Hall-D photon source and GlueX detector are commissioned in parallel.

Accelerator Systems is further divided into six systems: 1) SRF Cryomodules, 2) Beam Transport, 3) Linac RF and DC Power Systems, 4) Instrumentation, Controls, and Safety, 5) Extraction, and 6) Cryogenics. Each system's design solution document details system requirements and design solutions for these requirements. [4, 5, 6, 7, 8, 9]

Hall D: Hall D will provide all equipment necessary to produce the photon beam. This equipment includes crystal diamonds and amorphous targets to be used as bremsstrahlung radiators, a goniometer for precision alignment of the radiators, a quadrupole of type QP for focusing the scattered electrons on the Hall D tagger spectrometer, one dipole magnet with ∫Bdl sufficient to bend the 12GeV beam by 13.4°, detectors needed to analyze the electrons which generated the photon beam, an instrumented collimator (used to measure the photon beam centroid) in the entry cave of Hall D, and a pair spectrometer.

Electron beam emittance	**$\varepsilon_x < 10$ mm-μrad**
	$\varepsilon_y < 2.5$ mm-μrad
Electron beam energy spread	**< 0.1%**
Uncertainty in electron beam energy	**< 0.1 %**
Spot size @ radiator	**800 μm < σ_x <1600 μm**
	300 μm < σ_y <600 μm
Beam image size at 76m from radiator	**σ_x < 600 μm**
	σ_y < 600 μm
Beam halo*	**$<5\times10^{-5}$**
Beam position stability at collimator	**Δx < 200 μm**
	Δy < 200 μm
Electron beam current	**0.3 nA< I_e <3 μA**

*** Fraction of electron beam outside a radius of 5 mm at goniometer**

Table 1 Summary of electron beam characteristics needed for the GlueX experiment.

4. Interfaces between Hall D and the Accelerator

The Accelerator and Hall D systems, which require an interface between the two groups, are as follows, staring with systems in the tagger hall and then those in the experimental area:

1. The electron beam
2. Goniometer
3. Hall D Tagger quadrupole magnet
4. Hall-D Tagger dipole magnets
5. Electron beam dump
6. The vacuum system
7. The photon beam
8. Instrumented primary photon beam collimator and feedback system
9. Hall D collimator sweep magnets
10. Photon beam dump
11. Hall D machine inhibit (FSD)
12. Personnel protection systems (PPS)
13. Machine protection systems (MPS)

In the following sections each of these interfaces will be defined.

1. The Electron Beam

The accelerator system groups will provide and install the beam transport system to the Hall D tagger hall. The beam transport system, as defined in this document, includes the beam pipe as well as numerous devices necessary to monitor and control the electron beam to include but not limited to BPMs, Harps, Viewers, Magnets, Ion Pumps, and BCMs [2, 4, 5, 6, 7, 8, 9]. The devices closest to the tagger hall will be described as they are most important for monitoring the beam quality. An instrumentation girder will be placed at the entrance to the tagger hall at 1860-NS on which the instruments in Table 2 will be mounted.

Device Name	Description
IPM 5C11B	Beam Position Monitor
IHA 5C11A	Harp wire scanner
ITV 5C11A	Viewer (phosphor screen)
MBD5C11AH	Horizontal steering magnet
MBD5C11AV	Vertical steering magnet
VIP5C11A	Ion Pump

Table 2 Beam monitoring devices placed at the entrance to the tagger hall.

Directly after the instrumentation girder will be a low current beam position monitor (iCLnApm2) which is the last beam monitoring instrument in front of the Hall D goniometer.

Halfway along the labyrinth to the electron beam dump will be a beam position monitor (IPMD 100 BPM) and a beam current monitor (1BCD 100). Finally directly in front of the beam dump will be a beam viewer (ITVD 100). The devices inside the labyrinth are summarized in Table 3.

Device Name	Description
IPMD100	Beam position monitor
1BCD100	Beam current monitor
VBVD101	Beam Viewer

Table 3 Devices places along the labyrinth to the electron beam dump.

All the beam line instruments above are under the responsibility of the accelerator systems group and will be controlled by the accelerator systems groups and/or accelerator operations division. Information from these instruments will be available to the Hall D experiments through the machine controls system EPICS.

2. Goniometer:

The goniometer is located upstream of the tagger magnet and is used to hold the diamond or other radiators which produce the photon beam. The goniometer will be controlled by Hall D using its own control system provided by Hall D. The goniometer is an ultra-high vacuum device which poses no contamination hazard to the accelerator. Accelerator Operations must insure that the electron beam strikes the diamond crystal inside the goniometer which is precisely positioned along the nominal beam line. The tuning of the beam on the goniometer radiator will be discussed in the startup plan and a standard operating procedure will be developed for the radiator alignment procedure. The alignment procedure for the crystals consists of rotating the radiator independently about different axes, while monitoring the energy spectrum of the bremsstrahlung photons. From this data set the exact orientation of the crystal planes can be measured and the optimum orientation of the crystal determined. Hall D will provide the information concerning the crystal position to accelerator operations via EPICS.

3. Hall D tagger quadrupole magnet:

Hall D will provide and install a QP quadrupole magnet, the stand for the quadrupole, the water cooling, the power cables, and the power supply. Accelerator system groups will provide the mapping of the magnet and the controls for magnet and power supply including the temperature switch interlock [5, 6]. The QP quadropole, with nominal field gradient of -0.5215 kG/cm and a length of 31.26 cm, will be installed by Hall D downstream the goniometer. This magnet is needed to focus the electrons which underwent bremsstrahlung on the tagger spectrometer consisting of a fixed scintillator hodoscope and movable high-resolution microscope. The quadrupole will be controlled by Accelerator Operations and/or Accelerator System Groups but set at the constant current specified by Hall D. Dedicated calibration measurements which determine the focus of the electron fan on the tagging spectrometer detectors will need to be performed periodically by Accelerator Operations. Operating procedures for these calibration measurements will be developed between Hall D and Accelerator Operations.

4. Tagger dipole magnet:

Hall D will provide and install the tagger magnet, power supply, NMR probes used for field stabilization, and a PLC based control system with EPICS interface. The Accelerator System Groups will provide and install any additional equipment needed to interface the magnet to the PSS and MPS systems [6,7]. The tagger magnet has a 1.5T nominal magnetic field which bends the 12 GeV beam by 13.4° toward the electron dump. The tagger dipole magnet must be operated by accelerator operations as it is an integral part of the accelerator personnel protection system [7]. Small adjustments to the magnetic field during machine setup are acceptable, but once data collection has started the field must remain constant. The beam steering and control devices provided by the accelerator system groups must be sufficient to enable accelerator operations to correct the beam position on the electron dump without changing the current in the tagger magnet. This magnet will be mapped by Hall D at its nominal operating current.

5. Electron Beam Dump:

The Accelerator System Groups will be responsible for the electron beam dump. The gate to the labyrinth leading to the electron beam dump will be padlocked by the radiation control department. Access to the beam dump will be restricted by the radiation control department. Radiation from the beam dump could produce background in the tagger hodoscope. The projected rates of 2000 mrem/h at the start of the labyrinth under conditions of maximum operating beam current have been computed by the radiation control department and are acceptable for the Hall D experiments. Changes to the shielding design must be made in consultation with Hall D and the radiation control department [11].

6. Vacuum system

The accelerator system groups will provide and install a 1.5” gate valve (VBVD5C11A) directly downstream of the low current beam position monitor at 1871-NS, which is in front of the goniometer. The accelerator system groups will be responsible for the vacuum upstream of this valve and Hall D will be responsible for the vacuum downstream. Neither Hall D nor the accelerator system groups may vent their section of the beam line unless this valve is closed. The valve may only be opened with the mutual agreement of both Hall D and the accelerator system groups. The accelerator system groups will resume responsibility for the vacuum in front of the beam dump between 2030-NS and 2040-NS where they will provide and install a 2” gate valve (VBVD101) and Thermocouple gauge (VTCD 101). The vacuum system components at the entrance to the electron dump region are listed in Table 5 and detailed in the system’s design solution document [5, 7].

Device Name	Description
VBVD101	2” gate valve
VRVD101	Roughing Valve
VTCD101	Thermocouple gauge

Table 5: The machine vacuum system components in the Hall D tagger hall dump region.

Hall D is responsible for the vacuum between the valves VBVD5C11A and VBVD101. This is the region from the goniometer to the valve upstream of the electron beam dump. The ultimate pressure in the Hall D section when VBV5C11A is closed will be below 1×10^{-5} mbar. Hall D will provide, install, and control three pumping stations using turbomolecular pumps which will be used to evacuate the Hall D tagger beam line. One pump near the goniometer will reduce the pressure to the 1×10^{-5} mbar level for the machine. A second pumping station near the East wall of the tagger hall services the beam line between the tagger hall and Hall D. The third pumping station on the vacuum vessel of the tagger spectrometer evacuates this large vacuum vessel and provides pumping to the short section of beam line between the tagger vacuum vessel and the beam dump. All pumping stations will be instrumented with thermocouple pressure gages and cold cathode gages. Near the pumping station at the East wall will also be a valve where an accelerator system groups' portable roots blower pumping station can be attached for the initial evacuation of the vacuum system. Hall D will provide and install all vacuum equipment instrumentation and controls and will be read out and controlled by Hall D. Hall D will provide all information via EPICS to accelerator operations and the machine safety system as required [7]. Hall D will provide valve control capability to the accelerator system groups' valve control box so the isolation valves can be closed in case of vacuum failure. The logic of the valve control will be such that either the machine or Hall D may close the valves but they can only be opened if both parties enable the valves [10].

7. The Photon beam

The photon beam is produced by bremsstrahlung interactions of the 12 GeV electron beam in the diamond radiator. In order to produce a usable linear polarization the photon beam is collimated after a 76m drift length. After primary collimation, sweeping magnets and secondary collimation are needed to remove from the beam unwanted particles produced by interactions in the primary collimator. The collimated beam passes through the Hall D target and the Hall D experiment and finally enters the photon beam dump. The photon beam layout is shown in Figure 1. Hall D is responsible for the photon beam line and will provide information via EPICS to accelerator operations. The design of the photon beam line has been approved by the accelerator system groups and radiation control group.

8. Instrumented primary photon beam collimator and feedback system

An instrumented collimator will be installed at the entrance to the Hall D collimator cave and will measure the centroid of the bremsstrahlung photon beam with an accuracy of 200 μm and an update frequency of up to 2 kHz depending on electron beam current. This information will be provided to accelerator operations for purposes of precise steering the electron beam on the diamond radiator and the photon beam on the primary collimator. Accelerator System Groups will provide and install a fast feedback steering system to stabilize the position of the electron beam spot on radiator and the photon beam spot on the instrumented collimator to the precision listed in table 1 above [7].

9. Hall D collimator sweep magnets:

Hall D will provide and install a pair of sweeping magnets in the collimator extension of Hall D. One of these magnets will be a permanent magnet the other magnet an electromagnet. The electromagnet will be controlled by Hall D.

10. Photon Beam Dump:

The photon beam dump is the responsibility of the radiation control department. ~~The accelerator system groups provide the interface to the radiation control department for issues related to the photon beam dump [7].~~ Hall D will place less than 20% of one radiation length of material in the path of the collimated photon beam under normal running conditions. During special calibration runs at low current a total absorption counter, provided and installed by Hall D, may be placed in the photon path. Procedures for these calibration runs and any other dedicated measurements will be established between Hall D and accelerator operations.

11. Hall D machine inhibit (FSD):

Hall D will provide signals to the accelerator FSD which will be used to inhibit the transport of beam to the tagger hall. In the event of equipment failure or large backgrounds, Hall D can inhibit the transport of the electron beam to the tagger hall. A beam shutter will be provided in the beam transport region which is described in the accelerator design solution document for safety systems [7].

12. Personnel protection systems (PPS):

Two parts of the Hall D provided equipment are integrated into the CEBAF PPS [7].

A Beam Transport Monitor (BTM) provided by the Accelerator System Groups will continuously monitor the currents in the magnets which steer the beam into the tagger hall and the tagger magnet energy setting. The currents in these magnets are compared and if the currents deviate from the combination needed to transport the beam to the hall and beam dump then the beam will be dumped. The currents in each magnet will be measured with a 3-fold redundancy. To implement this system, the tagger magnet will be controlled by accelerator operations.

In the event there is a failure in the above active system, a passive fail-safe system is foreseen that makes it impossible for the electron beam to be transported to Hall D. Hall D will provide and install a permanent dipole magnet with an integrated field strength of 0.822 Tm in the photon beam line at about 2030-NS. This magnet was constructed at Fermi National Laboratory and is of type PDV. The dipole gap is such that a 1 ½ by 3 ½ elliptical beam pipe fits down the bore. The magnet iron is 145" long. This magnet will be mounted downstream of the tagger magnet and forms part of the personnel protection system. It has sufficient strength to insure that the 12 GeV beam cannot be transported into Hall D. Any electron beam passing through the dipole will be steered down toward the floor of the tagger cave.

The permanent magnet dipole has no active components. The exact position of the magnet in the hall has been agreed upon by Hall D and the accelerator system groups [5]. Accelerator system groups will inspect magnet installation for polarity to ensure the electron beam passing through this dipole will steer down toward the floor of the tagger cave [5].

In addition to the above the accelerator system groups will provide and install ion chambers in the hall along the East wall to detect transient beam loss associated with failed optics.

13. Machine Protection System (MPS):

The tagger Machine Protection System (MPS) is an extension of the existing CEBAF MPS architecture. Fast shutdown (FSD) modules are linked in a tree structure back to the CEBAF injector. The FSD will monitor interlocks on the beamline and electron dump. FSD inputs include vacuum/valve status, beam dump cooling, radiator status, and the experiments inhibit. Beam Loss Monitors (BLM) will be positioned at tight apertures and bends where loss is most likely. Ion chambers (ICs) will be positioned near the radiator to detect beam loss in a thick target. The existing CEBAF Beam Current Accounting (BCA) System will include a cavity monitor at the electron beam dump. The BLM, ICs, and BCA trip the beam off through the FSD network when a fault is detected. If any gate valve closes or there is a vacuum failure the beam will also be disabled. The Beam Envelope Limit System (BELS) system monitors the total beam power in CEBAF to ensure the JLab operations and DOE safety envelopes are not exceeded. The existing BELS will be extended to account for beam power directed to the tagger/Hall D. Energy calculated from the BTM is multiplied with the value of the current measured in the BCA system. A local limit for the tagger area will provide protection for the beam dump. In addition, the beam power in the electron dump is combined with the beam power for the other experimental areas to verify the total beam power for the facility.

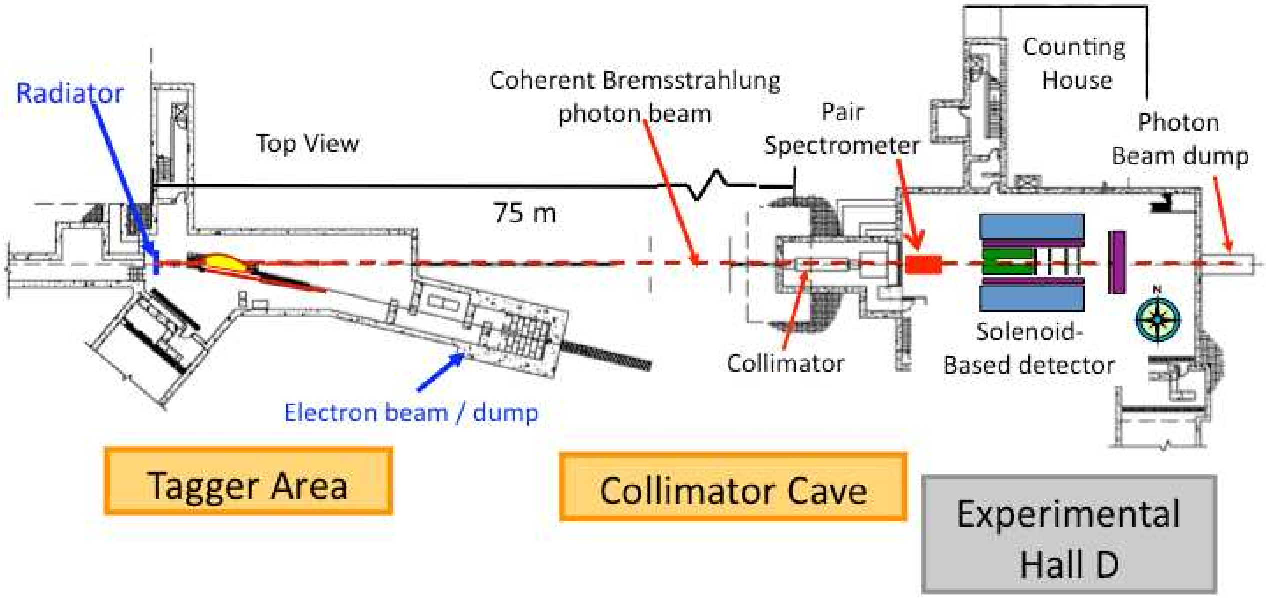

Figure 1 Overview of the tagger hall and Hall-D.

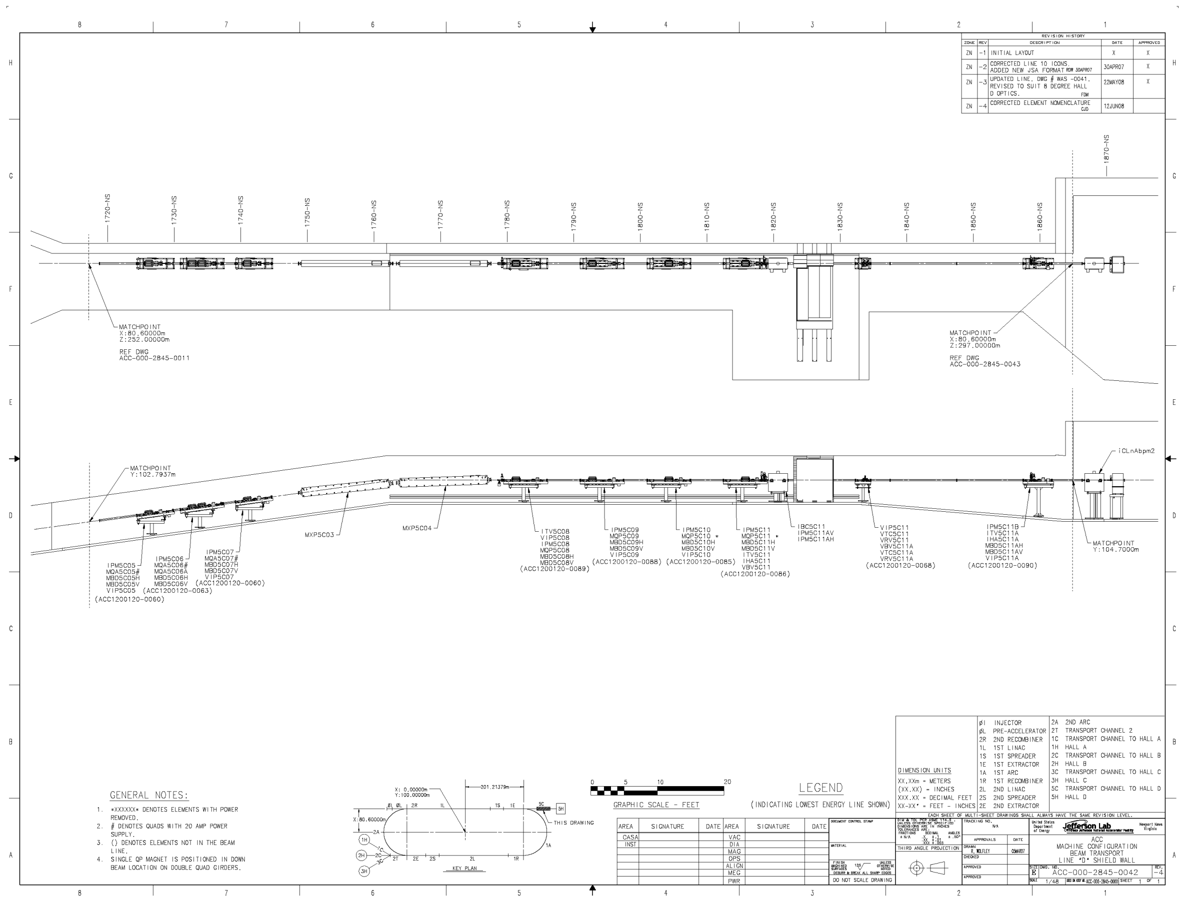

Figure 2 Machine interface drawing (ACC-000-2845-0042) for the beam line components upstream of the tagger area

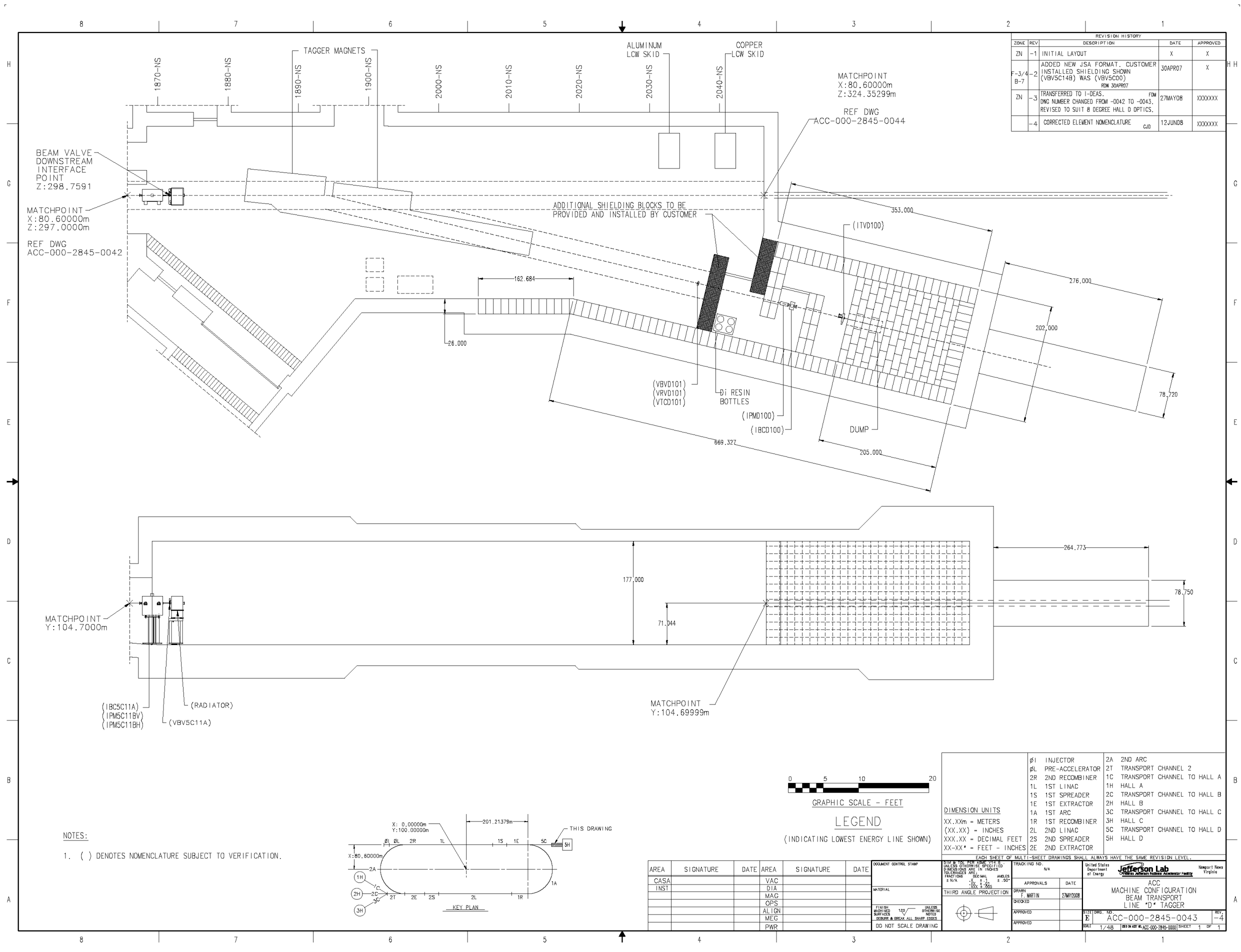

Figure 3 Accelerator – Hall D interface drawing (ACC-000-2845-0043) for the tagger area.

5. Reference Documents

[1] 12GeV Interface Control Document Accelerator and Experimental Systems (Accelerator and Hall D), Draft 5

[2] 12GeV Upgrade Accelerator Systems Requirements Document, Version 1.2

[3] Provide document name here that provided information for table 1 (i.e., GlueX Tagger Review Document…)

[4] 12GeV Upgrade Project Design Solution Document Cryomodules, Version 1.0

[5] 12GeV Upgrade Project Design Solution Document Accelerator Systems Beam Transport, Version 1.1

[6] 12GeV Upgrade Project Design Solution Document Accelerator Power Systems, Version 1.0

[7] 12GeV Upgrade Project Design Solution Document Instrumentation & Controls/Safety Systems, Revision 0

[8] 12GeV Upgrade Project Design Solution Document Accelerator Systems Extraction, Version 1.2

[9] 12GeV Upgrade Project Design Solution Document Cryogenic Systems, May 31, 2007

[10] A detailed interface document for the logic of the valve controls for the vacuum system needs to be developed and referenced here.

[11] Erik Abkemeier, Pavel Degtiarenko, Keith Welch, Radiation Control Department, “Shielding Basis for Hall D Complex,” JLAB-TN-08-033