INTERFACE CONTROL NON-DOCUMENT

ACCELERATOR AND EXPERIMENTAL SYSTEMS

ACCELERATOR AND HALL D

DRAFT 6

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TABLE OF CONTENTS

ACRONYMS 4
1. Project Mission...5
2. System Roles 5
3. System Requirements 6
4. Interfaces between Hall-D and the accelerator 7

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
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
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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1. Project Mission

The 12 GeV CEBAF Upgrade would increase the available energy of the facility from 6 GeV to 12 GeV, and add to its experimental capabilities in order to more fully explore the nature of non-perturbative QCD as manifested in the nucleus, plus potentially solving the riddle of quark confinement.

2. System Roles

Accelerator Systems:	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.
Experimental Systems:	The Hall-D systems will provide a diamond radiator held with a precision goniometer which combined with the 12 GeV electron beam from the accelerator produces a polarized photon beam. The overall setup of the electron and photon beam in relation to Hall-D is shown in Figure 1. This photon beam propagates from the Hall-D tagger hall to Hall-D itself. The momentum of the electrons which radiate the polarized photons is analyzed in the tagger spectrometer thereby measuring the energy of the radiated photons. A collimation system at the entrance to Hall-D defines the linearly polarized beam of photons necessary for the Hall-D physics goals.

Details of the tagger hall containing most 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. During the commissioning phase it is understood that the machine will not perform up to these specifications. A detailed commissioning plan will be made to enable both the machine to optimize its performance and commission all its subsystems while the Hall-D photon source and GlueX detector are commissioned in parallel. ~~During the commissioning phase the emittance may be up to a factor of 5 worse.~~

Hall D: The Hall-D systems will provide all equipment necessary to produce the photon beam. This includes a goniometer for precision alignment of the diamond radiator, a QP quadrupole for focusing the scattered electrons on the Hall-D tagger spectrometer, one dipole magnet with ∫B·dl sufficient to bend the 12GeV beam by 13.4°, and the active collimator (used to measure the photon beam centroid) in the entry cave of Hall-D.

Electron beam emittance	**ε_x < 10 mm-μrad**
	ε_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*	**<5×10^{-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:

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

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

1. Electron Beam

The beam transport system to the Hall-D tagger hall includes numerous devices necessary to monitor and control the electron beam. 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 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 machine group will be controlled by the accelerator division. Information from these instruments will be available to the Hall-D experiments through the machine controls system EPICS.

2. 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 must be 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 GlueX target and the GlueX detector 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. The design of the photon beam line has been approved by the machine group and Radcon.

3. Instrumented primary photon beam collimator

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 1 kHz depending on electron beam current. This information will be provided to the machine for purposes of precise steering the electron beam on the diamond radiator and collimator system.

4. Vacuum system

The machine will provide and control 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 machine group 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 machine 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. The accelerator will resume responsibility for the vacuum in front of the beam dump between 2030-NS and 2040-NS where they will provide 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.

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.

The vacuum system for which Hall-D is responsible starts after the machine valve VBV5c14B. The ultimate pressure in the Hall-D section when VBV5C11A is closed will be below 1×10^{-5} mbar. Three pumping stations using turbomolecular pumps are foreseen 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, one pumping station near the East wall of the tagger hall services the beam line between the tagger hall and Hall-D, and one 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 group’s portable roots blower pumping station can be attached for the initial evacuation of the vacuum system. All the Hall-D vacuum equipment will be read out and controlled by Hall-D. Hall-D will provide all information to the machine control system and the machine safety system as required. Hall-D will provide valve control capability to the machine group's 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.

5. Goniometer:

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. The accelerator 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 is discussed in the startup plan and a standard operating procedure will be developed for the radiator alignment procedure. Hall-D will provide the information concerning the crystal position to the machine.

6. Hall-D tagger quadrupole magnet:

A QP quadrupole with nominal field gradient of -0.5215 kG/cm and a length of 31.26 cm will be installed after 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 the machine group 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. Operating procedures for these studies must be developed between Hall-D and the machine.

7. Tagger dipole magnet:

The tagger magnet has a 1.5T magnetic field and bends the 12GeV beam by 13.4°. The tagger dipole magnet must be operated by the accelerator as it forms part of the personnel protection system. The field in the magnet will be adjusted to 1.500 T which is needed for the accurate operation of the tagging spectrometer. The beam steering and control devices provided by the accelerator must be sufficient to enable the accelerator to steer the 12 GeV beam onto the beam dump without changing the current in the tagger magnet.

8. Hall-D collimator sweep magnets:

A pair of sweeping magnets will be installed 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.

9. Hall-D machine inhibit:

The machine will provide to Hall-D a beam inhibit system. 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 radiation protection documents.

10. Personnel protection systems (PPS):

Two parts of the Hall-D provided equipment are integrated into the CEBAF PPS.

The tagger dipole magnets bend the un-degraded fraction of the CEBAF 12 GeV beam by 13.4° toward the electron beam dump. The accelerator will continuously monitor the currents in the magnets which steer the beam into the tagger hall and the tagger magnet itself. 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 needs to be controlled by the accelerator.

In the event there is a failure in the above active system, a passive system is foreseen that makes it impossible for the 12 GeV beam to be transported to Hall-D. A permanent dipole magnet with an integrated field strength of 0.822 Tm will be installed 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.

11. Machine Protection System (MPS):

In order to detect any beam in the tagger hall in the event of the failure of the magnet current system the machine will install ion chambers in the hall along the East wall. The MPS will be able to close all vacuum valves.

12. Electron Beam Dump:

The accelerator 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 protection group. Access to the beam dump will be restricted by the radiation protection division. Radiation from the beam dump could produce background in the tagger hodoscope. The projected rates of 2000 mrem at the start of the labyrinth under conditions of maximum operating beam current have been computed by Radcon and are acceptable for the Hall-D experiments. Changes to the shielding design must be made in consultation with Hall-D.

13. Photon Beam Dump:

The photon beam dump is the responsibility of the JLAB radiation protection group. The accelerator group provides the interface to the radiation protection group for issues related to the photon beam dump. 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 will be placed in the photon path. Procedures for these calibration runs will be established with the machine group.

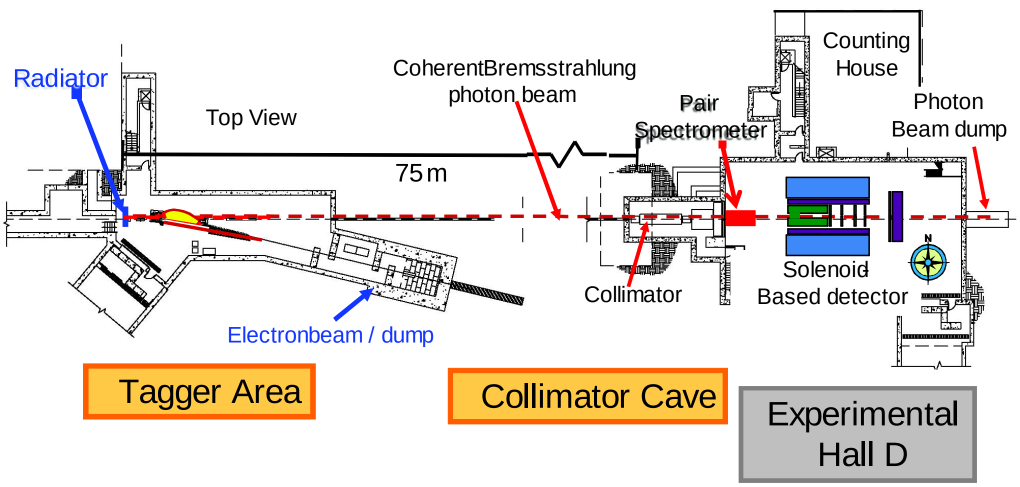

Figure 1 Overview of the tagger hall and Hall-D.

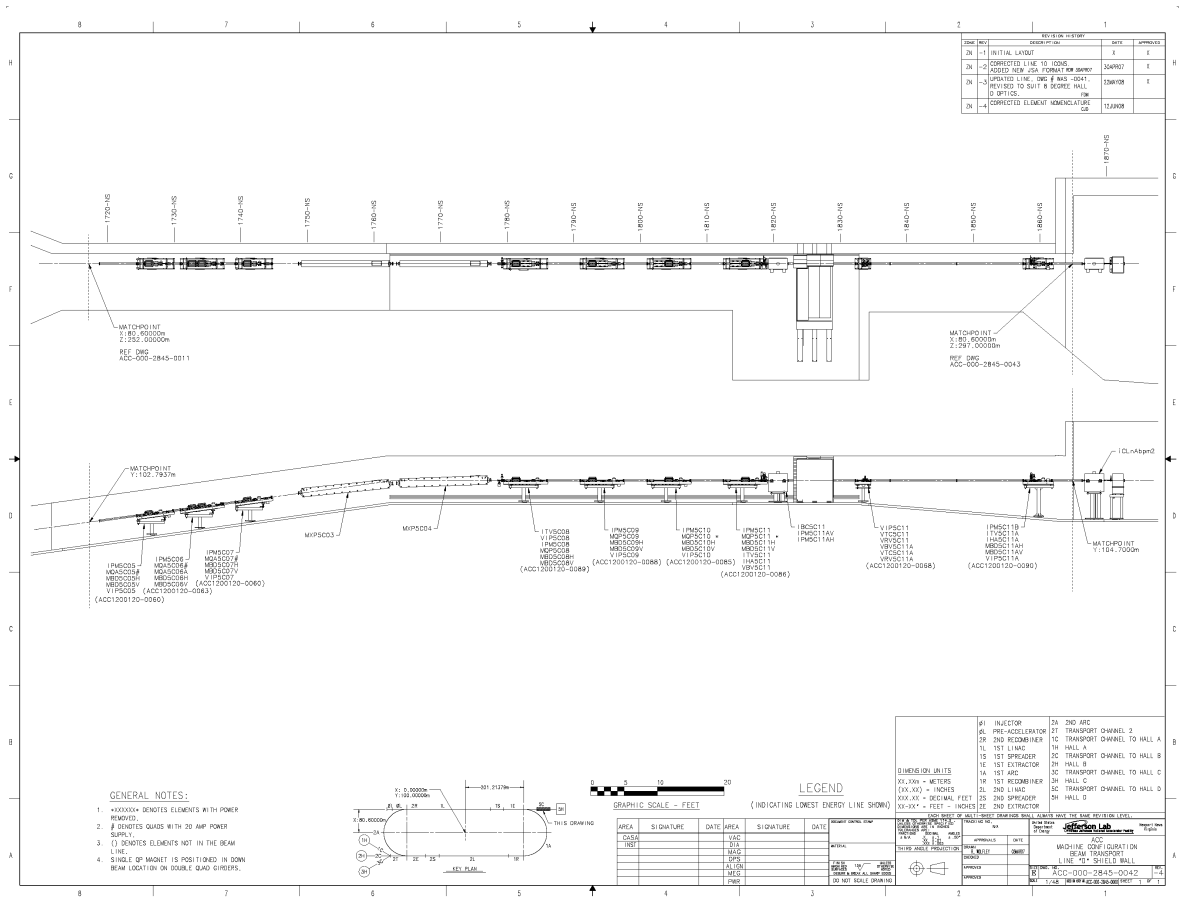

Figure 2 Machine interface drawing for the beam line components upstream of the tagger area

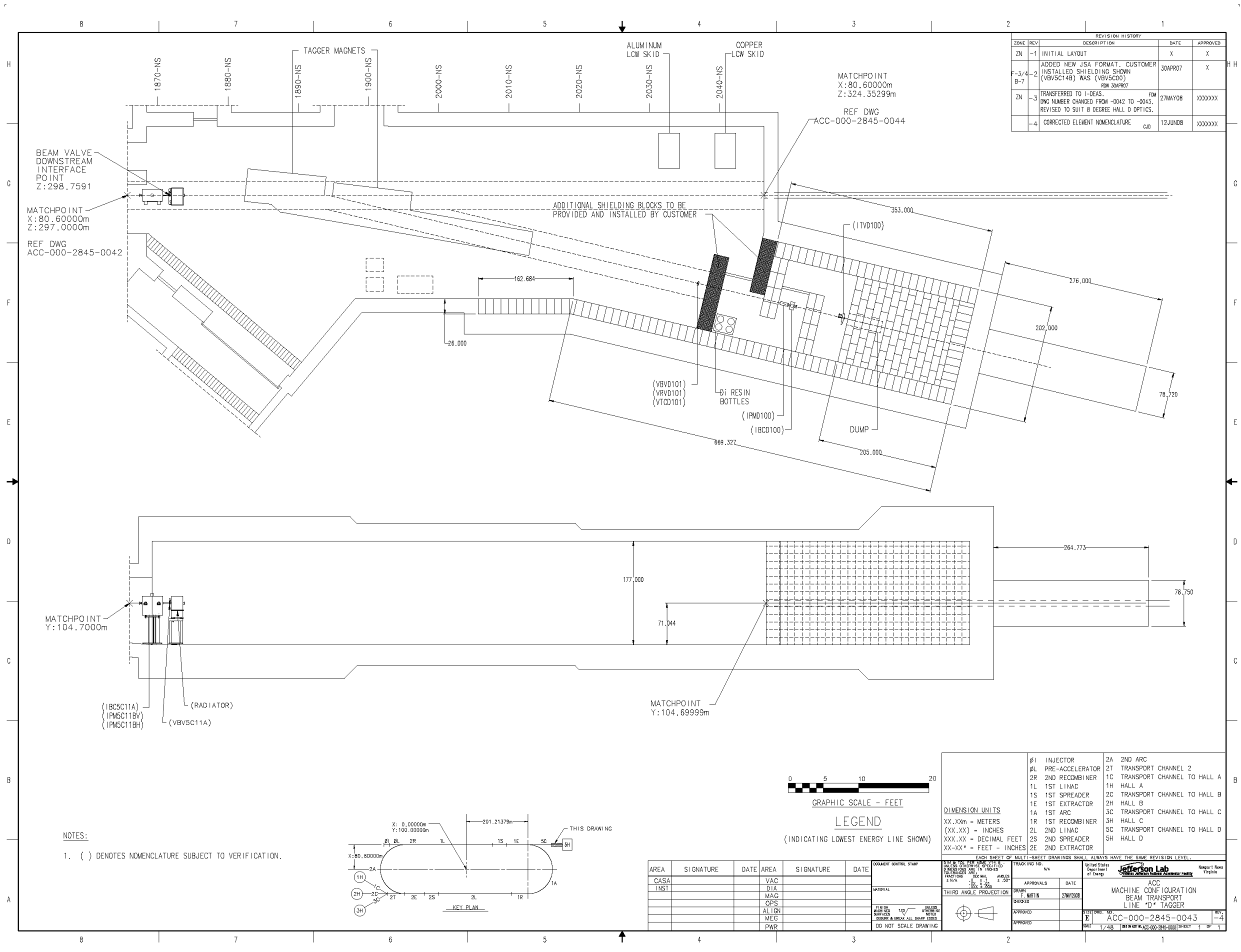

Figure 3 Accelerator – Hall-D interface drawing for the tagger area.