Physics Requirements for LCLS

Conventional Facilities

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Brief Summary: This document records the system level requirements for LCLS Conventional Facilities

Keywords: Sector 20, Magnetic Measurement Facility, Main Control Center, Linac, Research Yard, Access Road, Beam Transport Hall, Undulator Hall, Front End Enclosure, Beam Dump, Near Experimental Hall, X Ray Transport and Diagnostics Hall, Far Experimental Hall, Central Laboratory and Office Complex

Key WBS #'s: 1.9

Contents

1 Purpose of Document

The intent of this Physics Requirements Document (PRD) is to record system level requirements that must be met in the construction and modifications carried out by the system manager for Conventional Facilities (CF) of the LCLS project. These requirements for CF are derived to meet the overall performance requirements recorded in the LCLS Global Requirements Document (GRD)[1]. The CF system manager will use this PRD in writing Engineering Specification Documents (ESD's) which then become the record of the basis of the architectural and engineering design and other CF activities.

2 General Remarks

2.1 Types of Requirements

There are basically two types of requirements distinguished in this PRD.

Technical Requirements Technical requirements are singled out because of the sensitive and unique scientific and technical equipment of the LCLS. Specifications regarding thermal stability, foundation settlement, and vibration levels are typical technical requirements.

Program Requirements These consist of conventional architectural requirements such as number of offices and square footage and location of various types of space.

General site requirements that would pertain to any conventional construction on the SLAC site are not included in this document. They are left for inclusion in the "Engineering Specifications Documents" (ESD's) that are written by the system manager. Requirements for utilities, service buildings and other infrastructure that come about to meet the requirements defined in this document will likewise be included in the ESD's for CF. The main ESD for CF is the 'Design Guidelines' submitted as part of the Request for Proposal for Title I and II Architectural and Engineering Services. [2]

2.2 Source of Requirements

These requirements were derived to meet the requirements in the Global Requirements Document (GRD) for the LCLS and were arrived at in consulation with and input from system managers, other system physicists and LCLS project management. The goal was to obtain a consistent set of requirements across all LCLS systems that satisfy the overall GRD requirements that can be met in a timely and cost effective way.

3 Requirements

The requirements are organized by different work areas as identified in the LCLS WBS. Within each work area requirements are denoted by type as explained above.

3.1 Sector 20

Modifications of the Sector 20 Alcove and the construction of an RF Hut are required to house the LCLS Injector Laser and associated equipment and temperature sensitive RF equipment. Cable trays connecting the RF Hut with the Injector injector beamline area below are also required. [3]

3.1.1 Technical

Technical requirements for sector 20 CF work are:

Alcove		
Vibration criteria, max rms @10 Hz	2000	μin/s
Air temperature stability	1	$^\circ C$
Equipment heat load on HVA, max	6	kW
Acoustic noise level from klystron gallery	50	dB
RF Hut		
Air temperature stability	± 0.3	$^\circ C$

3.1.2 Program

The Alcove Improvements shall include a Laser Room, a Load Lock Room and a Control Room. The total gross square footage shall be at least 2000 sf at grade level adjacent to the Klystron Gallery. The Laser Room will be environmentally controlled equivalent to a class 100,000 clean room. A 9 ft clear height is required for the laser room.

The RF Hut will be located inside the existing Klystron Gallery over two existing penetrations which lead down to the accelerator tunnel below. The ceiling height in the RF Hut must be at least 2.75 meters high [9 feet].

3.2 Magnetic Measurement Facility (MMF)

CF must provide housing for the LCLS MMF. The MMF will be used to tune, measure and store LCLS undulator magnets and associated equipment.

3.2.1 Technical

The magnets to be measured and metrology equipment are temperature sensitive and a very high degree of accuracy is required.[7] Therefore the MMF housing needs to have precise temperature control. Excessive vibration is also detrimental and should be mitigated where practical. Specific requirements are listed below:

Air temperature stability	± 0.1	$^\circ C$
Nominal air temperature	23.5	$^\circ C$
Nominal air temp range	18.5-28.5	$^\circ C$
Vibration tolerance at floor	0.5	μm rms

The 'Nominal air temp range' is the range over which the temperature can be controlled. This is needed to measure the temperature coefficient of the undulator magnetic strength.

3.2.2 Program

The MMF needs to encompass an area approximate 3000 square feet located within existing SLAC Building 81.

3.3 Main Control Center Upgrade (MMC)

Modifications to the existing SLC control center are required to accommodate additional control equipment and LCLS personnel. This may involve expansion or renovation of existing facilities.

3.4 Linac

CF needs to modify some existing utilities to support the new bunch compressors. as needed.

3.5 Research Yard Modifications

To transport the electron beam from the existing Linac to the new Undulator Hall CF must provide a new structure called the Beam Transport Hall (BTH) in the Research Yard. Related to this CF must make modifications to the Research Yard to accommodate the new BTH, including the demolition of the FFTB housing.

3.5.1 Technical

Scheduling of Research Yard Modifications must be coordinated with the operational schedule of the FFTB and other accelerator operations through the SLAC management.

3.5.2 Program

Minimize impact.

3.6 Access Road and Beam Transport Hall

A new housing for the accelerator elements between the linac and the Undulator Hall is required, called the Beam Transport Hall (BTH). The BTH is sometimes referred to as the LTU (Linac-To-Undulator Hall). An Access Road that connects the north and south halves of the Research Yard by going around the BTH is required as well.

3.6.1 Technical

Shielding The walls, ceiling, floor and access points to be constructed in the BTH will comprise a major part of the radiation shielding needed for the LCLS. CF is required to work with the Radiation Physics group to develop specific thickness, material and layout designs that is compliant with the SLAC Radiation Safety Policy and approvable by the SLAC Radiation Safety Committee.

The shielding requirements for CF in the BTH are to be based on the requirements of the GRD which include,

- Maximum operating beam power of 5 kW.
- Maximum credible incident beam power of 150 kW.

A detailed analysis of the Title I CF design [6] shows an example of a compliant shielding design. It includes,

Quantity	Value	Units
Wall thickness (concrete eqv.)	70	in
Ceiling thickness (concrete eqv.)	48	in

Floor Height The height of the floor of the undulator shall be 1.400 m below the Beam Centerline as defined Appendix **??**. The floor should not follow the Earth's curvature but is determined at one point as described in the document. The tolerance on the floor height shall be 1/4 inch over any 10 ft span.

Width The location of the centerline of the Hall shall be 1.25 m from the beam centerline where the beam centerline is defined in Appendix A.

Location The location and length of the BTH and its relationship to some key accelerator is depicted schematically in Figure A.

Thermal Environment CF shall provide a means to maintain air temperature in the BTH within the following values during normal operation:

Nominal Air Temperature	28.5	$^{\circ}C$
Max Air Temeperature	30.0	$^{\circ}C$
Min Air Temperature	24.5	$^{\circ}C$

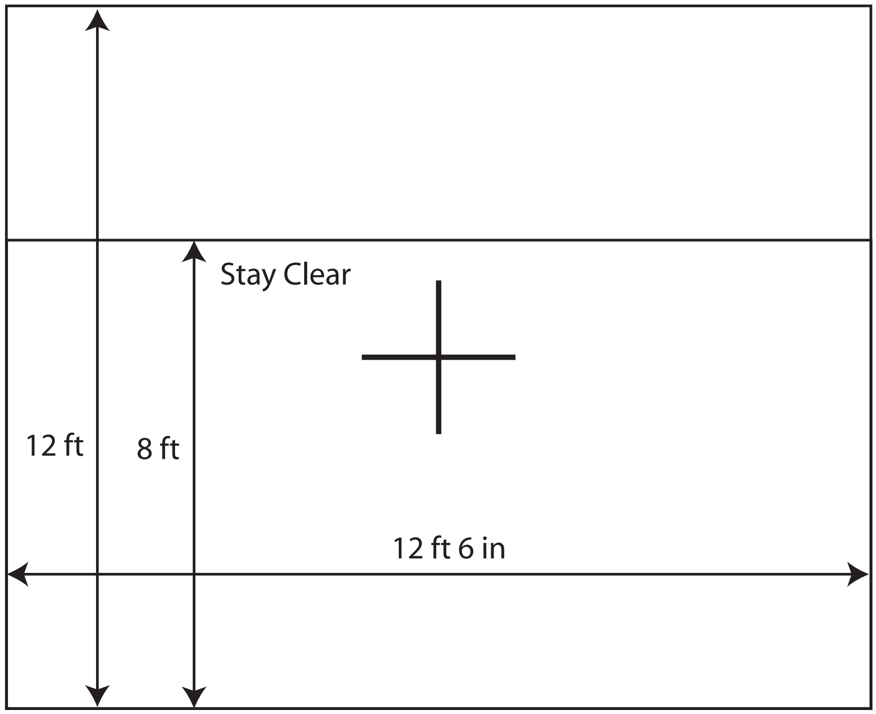

Figure 1: Minimal cross section and stayclear requirements the Beam Transfer Hall.

3.6.2 Program

Beam Transport Hall The Beam Transport Hall (BTH) shall provide a cross sectional area encompassing 14.5 ft wide by 12 feet height. CF utilities shall generally remain outside of an area of 14.5 ft width by 8 ft high throughout the hall. See Figure 1. This width is considered adequate for two undulator in mirror configuration. The BTH shall consist of an above ground concrete tunnel like structure bisecting the SLAC Research Yard that will house the LCLS electron beam line. The purpose of the BTH is to continue the electron beam from the Linac into the Undulator Hall, Front End Enclosure and Beam Dump.

The BTH extends from the end of the Beam Switch Yard wall, Station 109.35 where there is a step in the foundation height, downstream in the direction of the beam for approximately 230 meters. The final eight (8) meters of the BTH shall house the Tune-Up Dump which contains a solid copper block with localized shielding. The downstream end of the BTH shall include a physical thermal barrier separating the BTH from the Undulator Hall. The BTH shall be provided with heating, cooling, ventilation and smoke purge systems. A fire sprinkler system shall be provided throughout the BTH. The location and length of the BTH and its relationship to some key accelerator is depicted schematically in Figure A.

Some means must be provided for pedestrian traffic over the BTH.

Road Improvements An Access Road is required that connects the north and south access roads into the Research Yard by going around the BTH. The primary design criteria for the connecting access road is to accommodate life safety and emergency vehicles; providing proper road width and radii is a minimum requirement.

The north access road into the Research Yard must be modified to accommodate "low boy" trucks.

3.7 Undulator Hall

A new structure to house the LCLS Undulator is required. The structure shall have sufficient space to house, in the future, a second identical undulator in a symmetrical configuration.

3.7.1 Technical

Thermal Environment The Undulator Hall provide a tightly control thermal environment for the technical components within. Specific tolerances and values are listed below:

Quantity	Value	Units
Air Temperature (nominal)	23.5	°C
Max. Air Temp Deviation	±0.2	°C
Max Wall Temp Deviation from nominal	1.0	°C
Max 24 hr ave air Temp deviation	±0.1	°C
Max warming or cooling rate	0.05	°C/hr
Max flow velocity	1	m/s
Max relative humidity	45	%
Min relative humidity	35	%
Pressure	> 0	
Max temp under fault conditions	30	°C
Fan on/off control manual over-ride	yes	

Floor Height The height of the floor of the undulator shall be 1.400 m below the Beam Centerline as defined Appendix **??**. The floor should not follow the Earth's curvature but is determined at one point as described in the document. The tolerance on the floor height shall be 1/4 inch over any 10 ft span.he tolerance on the floor height shall be 1/4 inch over any 10 ft span.

Alignment and Survey Shafts The construction of vertical shafts to the surface from the Undulator Hall is required where needed for SLAC Alignment purposes.

Vibration Attempts should be made to mitigate vibration of the undulator foundation, especially due to adjacent vehicular traffic, and due to large reciprocating mechanical equipment. The vibrations levels should at no point in the UH exceed 1 μm rms integrated over frequencies greater than 1 Hz.

3.7.2 Program

The UH shall be a tunnel commencing from the downstream end of the BTH thermal barrier. The UH shall extend 175 meters in the direction of the beam to the downstream end of the UH

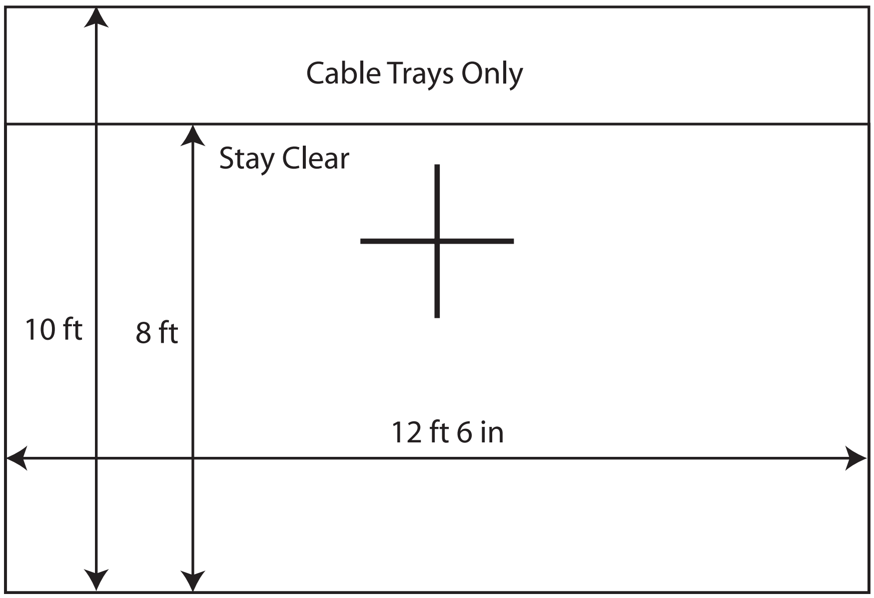

Figure 2: Minimum cross sectional size of the Undulator Hall.

where it shall be enclosed by another physical thermal barrier separating the UH from the Beam Dump/Front End Enclosure. The purpose of the UH will be to contain 33 undulator magnets and associated equipment as it continues the electron beam to the Front End Enclosure and Beam Dump, therefore temperature and foundation stability are critical to a successful design. Access into the UH will be through an entry provided from the BTH. The location and length of the UH and its relationship to some key accelerator is depicted schematically in Figure A.

Minimum cross sectional size is shown in Figure 2. This is considered sufficient cross sectional width to accommodate a second undulator in a mirror configuration. No CF equipment is to intrude on the 8 ft height or 12 ft 6 in rectangle. Cable trays may be located in the space below 10 ft and above 8 ft.

3.8 Front End Enclosure

CF is required to provide an underground housing connecting the Beam Dump to the Near Experimental Hall. This structure is called the Front End Enclosure (FEE).

3.8.1 Technical

Provide an access shaft or pathway from the FEE for gas piping to an accessible area.

CF shall provide air conditions such that a ± 1 °C temperature can be maintained near room temperature.

3.8.2 Program

The cross sectional area should encompass an area of 14.5 ft wide by 12 feet height. There should be 8 ft height clear of all CF equipment.

3.9 Beam Dump

CF shall provide underground housing and infrastructure, called the Beam Dump, where the X Ray beam is separated from the electron beam and the electron beam is captured.

3.9.1 Technical

Air conditioning in Beam Dump is required such that a ±1 °C temperature can be maintained. Two "trenches" will be required to allow passage of electron beamline to the dump (one trench is for a future identical beamline). Design of the trenches should allow for safe passage and in the Beam Dump Hall and adequate maintenance access to the accelerator components in the trenches.

Radiation Shielding The details of the shielding are explained in reference [6].

3.9.2 Program

Access to and around the Beam Dump with a minimum aisle width of 6 ft shall be provided.

The cross sectional area should encompass an area of 14.5 ft wide by 12 feet height. There should be 8 ft height clear of all CF equipment.The location and length of the FEE and its relationship to some key accelerator is depicted schematically in Figure A.

3.10 Near Experimental Hall

Down-beam of the Beam Dump CF is required to construct a Near Experimental Hall (NEH).

3.10.1 Technical

CF shall provide air conditioning such that a room air temperature can be maintained within 1 °C throughout the NEH. Mitigation of sources floor vibration due to large reciprocating equipment of vehicular traffic, such that vibration levels at the floor should not exceed 1 μm integrated over all frequencies above 1 Hz, should be performed.

3.10.2 Program

The NEH will extend for approximately 33 m in the direction of the beam. The minimum width of the NEH is specified at 14.5 m. It must contain three hutches and associated laboratory, preparation and control space for experiments. The hutches shall be aligned within the NEH in the direction of the x-ray beam. The interior finish dimension of each hutch shall be approximately 10 meters by 7 meters. On a level immediately above the hutches shall be a second floor which contains (at least) one Laser Bay of approximately 6 m by 32 m. The location and length of the NEH and its relationship to some key accelerator is depicted schematically in Figure A.

The location of the NEH with respect to the X Ray Beam Centerline shall be such that there is at least 1 m separation between the near wall parallel to the beam and the beam centerline. The X Ray beam centerline is a straight extrapolation of electron beam centerline from the Undulator Hall. See Appendix **??**.

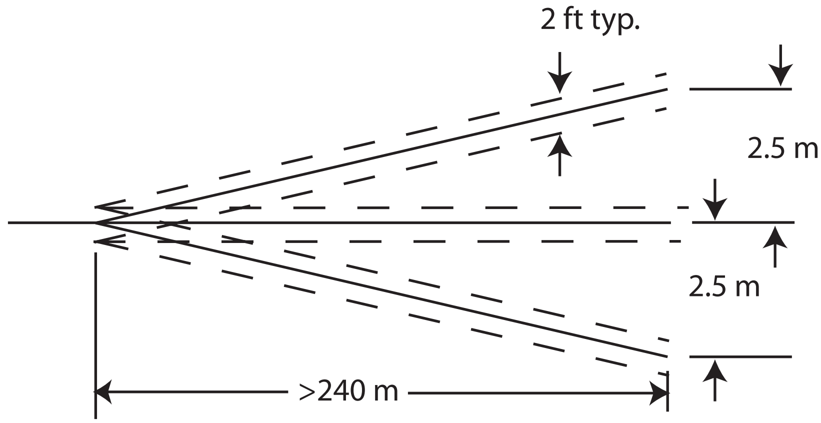

Figure 3: Layout of X Ray beamlines. The XTD tunnel must provide at least a 4 ft wide access route with at most one 'duck under' point, from one end of the XTD to the other.

3.11 XRay Transport and Diagnostics Hall

A tunnel called the X Ray Tranpsort and Diagnostics Hall (XTD) connecting the Near Experimental Hall to the Far Experimental Hall is required.

3.11.1 Technical

Floor Elevation The height of the floor of the undulator shall be 1.400 m below the Beam Centerline as defined Appendix **??**. The floor should not follow the Earth's curvature but is determined at one point as described in the document. The tolerance on the floor height shall be 1/4 inch over any 10 ft span.The tolerance on the floor height shall be 1/4 inch over any 10 ft span.

3.11.2 Program

The length of the XTD shall be at least 240 m, starting after the end of the last hutch in the Near Experimental Hall. The XTD width shall be adequate to accommodate three X Ray beamlines, and a 4 ft clear aisle with one duck-under point. The beamline elements may be assumed to fit within a width of ±1 ft from each of the beam centerlines. The layout of the three beamlines are defined in Figure 3. The location and length of the XTD and its relationship to some key accelerator is depicted schematically in Figure A.

3.12 Far Experimental Hall

Construction of experimental hutches and associated shop and office space are required at the end of the LCLS facility.

3.12.1 Technical

Floor Elevation The height of the floor of the undulator shall be 1.400 m below the Beam Centerline as defined Appendix **??**. The floor should not follow the Earth's curvature but is determined at one point as described in the document. The tolerance on the floor height shall be 1/4 inch over any 10 ft span. The tolerance on the floor height shall be 1/4 inch over any 10 ft span.

3.12.2 program

The FEH shall include three hutches, approximately 7 by 10 m, and related office and shop space.The location of the FEH and its relationship to some key accelerator is depicted schematically in Figure A.

3.13 Central Laboratory and Office Complex (CLOC)

LCLS requires the construction of a complex of offices and laboratories to support staff and researchers.

3.13.1 Technical

Provisions for laboratory space shall include (6) six laser labs (non-certified clean room class 10,000).

3.13.2 Program

A complex of laboratories and offices is required to be constructed to house the research offices and laboratory space to accommodate LCLS users, scientific and support staff. Capacity of the CLOC should be assumed to be approximately 300 persons.

The gross area of the CLOC shall include 51,000 square feet of office or laboratory space. The planned use of the facility shall be heavily utilized during normal business hours but shall also have the ability to function in a normal building status during "off-hours". Provisions shall be made for all groups to perform its activities efficiently, safely and comfortably.

General office space shall be designed to be flexible with a combination of hard-walled offices and open landscaped systems furniture. An exhibition area shall be designed to provide spatial allowance to feature the LCLS research. Provide a small machine shop, electronics lab and model shop. Additional space shall include a computational center, storage rooms, mail room, reproduction room and other general amenities (i.e. kitchen, lounge, etc).

Conference room space shall include collaboration areas: (3) three small (5-8 capacity), (2) two medium (14-18) capacity, and (1) one large (40-50) capacity [the large room shall be designed to accommodate an acoustical divider]. A large lecture style facility shall be provided to accommodate a capacity of 100.

Parking shall be provided adjacent to or in the immediate surrounding area. Provisions for moderate landscaping shall be provided.

Location	description	x [m]	y [m]	z [m]
ZLIN15	Station 100	0	0	0
BSYEND	FFTB side of muon plug wall	0	-0.821761	176.020508
VBIN	start of vert bend system	0	-0.834188	178.682319
VBOUT	end of vert. bend system	0	-0.895305	204.865007
UNDBEG	start of undulator system	-1.25	-0.895305	517.000592
UNDEND	end of undulator system	-1.25	-0.895305	648.292592
DMPBEG	start of dumpline	-1.25	-0.895305	693.387007
DUMP	entrance faces of e- dump	-1.25	-3.180529	724.774453

Table 1: Reference points on the LCLS Beam Centerline given in the LCLS Coordinate System. Coordinates are given to the nearest micron.

A Beamline Definition

Many of the CF structures must be located with respect to the electron Beam Centerline (BC). This section defines where the electron BC is in space in terms of the 'LCLS Coordinate System' that is convenient for LCLS design. The LCLS Coordinate System is defined in [4]. It is derived from a the Linac Coordinate System that is in common use at SLAC. The points are generated from a 'MAD' input file used to model the LCLS accelerator, specifically LCLS04MAY04. Each point corresponds to an entry in the file. The reference input file is stored at http://www-ssrl.slac.stanford.edu/lcls/linac/optics/lcls.txt and will be a controlled document [8].

Points on the BC are defined in Table 1. In between the points the is a straight line, except between ZLIN15 and BSYEND, between VBIN and VBOUT, and between DMPBEG and DUMP; where a set of arcs and straight lines define the BC. In other words the BC is straight throughout the Beam Transfer Hall and Undulator Hall, from the end of the vertical bend until the beginning of the dump line.

References

[1] J. Galayda, Linac Coherent Light Source Project Requirements

[2] *A*rchitectural/Engineering Design Guidelines, LCLS Conventional Facilities Project Design Criteria, ESD 1.9-007

[3] D. Dowell's note

[4] E. Bong, P. Emma, C. LeCocq, T. Montagne, J. Welch, *LCLS Undulator Coordinate System*, LCLS technical note LCLS-TN–3-8, April 2004.

[5] http://www-ssrl.slac.stanford.edu/lcls/s2e/ Need to update this.

[6] S. Mao, et. al, Shielding Requirements for the LCLS Project,

[7] LCLS-TN-04-1, Requirements for the Construction of the LCLS Magnetic Measurements Laboratory, Feb 2004,

[8] , PRD 1.9-006

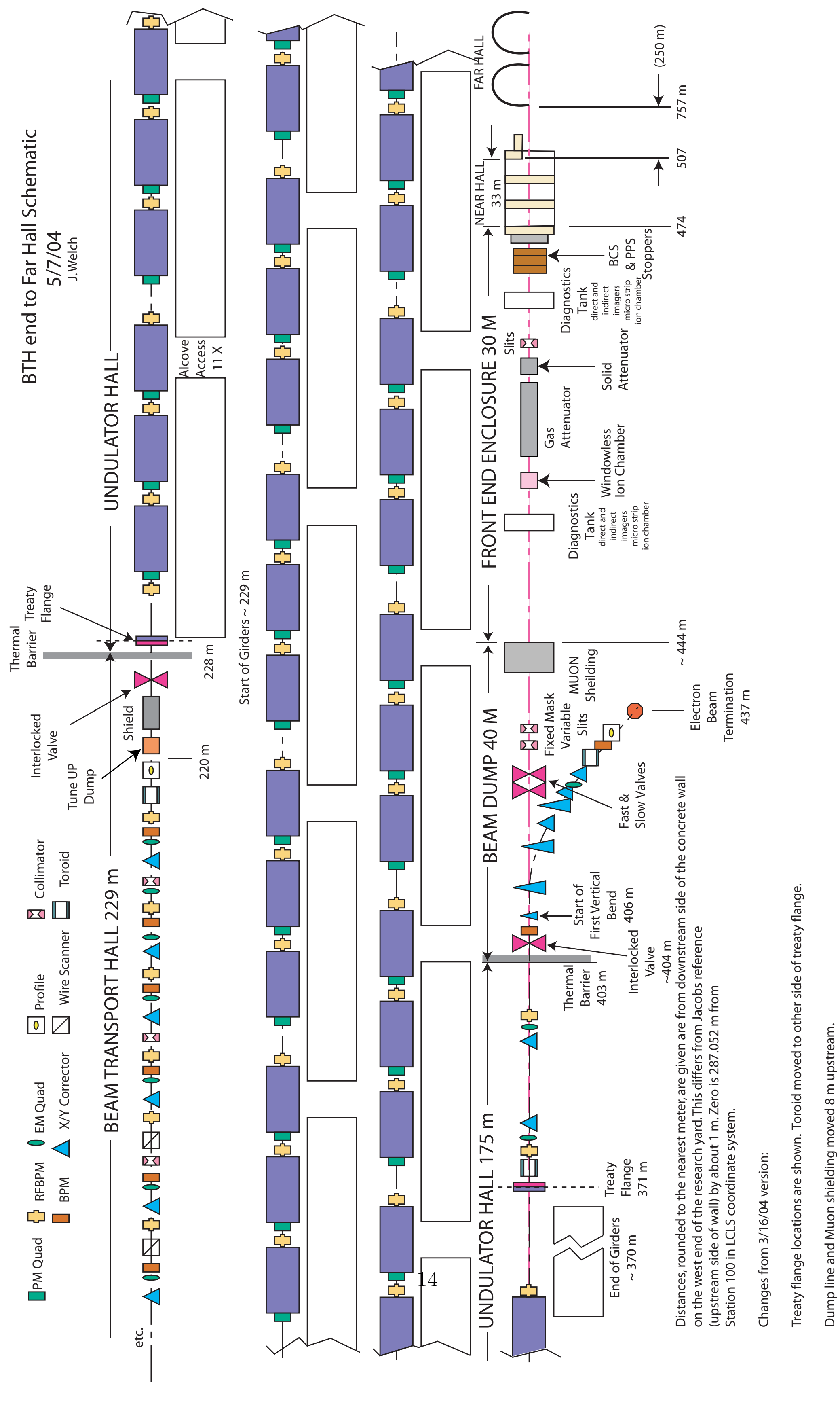

Figure 4: Schematic of important beamline components and boundaries of various halls.