LCLS Physics Requirements Document # 1.3-117	Linac	Revision 0

ELECTRON SAFETY-DUMP REQUIREMENTS

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Brief Summary

This specification summarizes the electron beam safety dump-line requirements, which is composed of permanent magnet dipoles and fixed aperture protection collimators all of which are located downstream of the main, powered dump magnets.

Change History Log

Rev Number	Revision Date	Sections Affected	Description of Change
000	Sep. 10, 2005	All	Initial Version

Stanford Linear Accelerator Center
Stanford Synchrotron Radiation Laboratory

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Electron Safety-Dump Requirements

The LCLS dump system must not only provide an appropriate device onto which the electron beam can be deposited, but must also prevent the electron beam from entering the x-ray beamline even under the most extreme accident scenarios. The need to change beam energies from 4.3 to 13.6 GeV over the course of hours (for beam-based undulator alignment), and the need to have a dump line with stringent optical properties for diagnostic purposes, precludes the simple solution of a dump line comprising only permanent-magnet dipoles such as that in the FFTB. Instead, a set of electromagnetic powered dipoles, and as backup, a set of permanent-magnet dipoles will be used to construct two dump lines in series: one upstream optically-matched operational vertical dump line comprised of powered DC magnets; and one downstream horizontal safety dump line comprised of permanent magnets. The scheme is shown in Fig. 1.

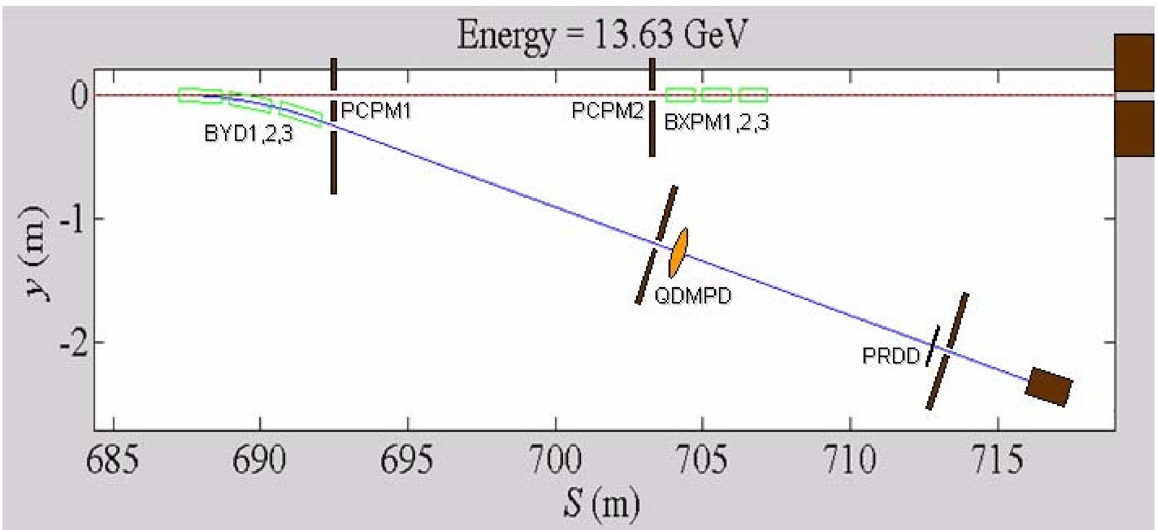

Figure 1. Plan view of upstream vertically bending powered dump line with three DC magnets (BYD1, 2, 3), and the downstream horizontally bending permanent magnet safety dump line with three permanent magnets (BXPM1, 2, 3). In this coordinate system the undulator ends at S = 646.965 m.

Under normal operating conditions, the electron beam will always be deposited on the operational (powered) dump, which bends down in the vertical direction, and the powered magnet configuration allows for maintenance of the desired optical properties of the dump line (*e.g.*, beam sice on the screen PRDD) while undergoing significant energy changes. In addition, three permanent magnet dipoles (BXPM1, 2, 3) will be situated on the x-ray beam line, down beam of the powered dipoles and rotated by 90 degrees in order to bend horizontally. Should the powered dipoles trip off, run at reduced power, or even be accidentally run in reverse polarity, the safety dump line will intercept any incoming primary beam before reaching the iron muon shielding that protects the downstream x-ray facilities from electron beams. The prevention of primary electron beam transport through the muon shield and into the x-ray facilities under any credible accident situation significantly affects the minimum standards that must be met for shielding and stopper design for these x-ray facilities.

The use of this permanent magnet arrangement is desired over interlocking of the powered dump line dipoles for a variety of reasons. It would be extremely difficult to meet the SLAC *three independent stopper* policy through interlocking of the power supply and/or of the bend magnetic fields (the policy also states that only one stopper of a set of three may be a magnet power supply). In addition, maintaining proper configuration control over this system as routine repairs are made to the power supply would prove challenging. Further, consider that proper configuration of the magnet cables from the power supplies, through any link boxes, and at the magnets themselves, would have to be controlled and maintained for safety purposes. All of these administrative requirements, in addition to being operationally oppressive, would be credibly subject to errors that could lead to accidental electron transport down the x-ray beam line. With the permanent magnet safety dump arrangement, and its confining protection collimators, confirmation and maintenance of the needed safety requirements are straight forward and not subject to error.

In addition to permanent magnets, the dump system contains strategically placed protection collimators that intercept stray beams, or restrict beam trajectories where necessary. These protection collimators (PCPM1 and PCPM2) must be designed to either absorb the full LCLS beam power, or be equipped with a pair of Beam Containment System (BCS) ion chambers that limit the beam power lost on the device. If designed to absorb the full allowed beam power, the device will likely be water cooled and would consequently have BCS-interlocked flow protection. The safety dump amounts to a protection collimator with a center aperture, allowing passage of x-rays through the muon shield; the safety dump should be able to absorb the full beam power. In either case, all protection collimators, and both the operational and safety dumps, must be equipped with burn-through monitors (BTMs). The BTMs are a last-resort device used to terminate runaway accident conditions where the BCS is compromised and where the beam may exceed its design envelope.

Ray traces have been developed to demonstrate the effectiveness of the proposed safety dump system. Figure 2 shows that electron beams cannot be steered past the safety dump. A variety of beam energies are plotted (from 3 to 17 GeV in 2-GeV steps), with 17-GeV as the worst case scenario, since lower energy beams are more easily swept clear of the safety dump aperture. This is the highest energy achievable with 10 sectors of acceleration. Several worst-case initial trajectory errors are also plotted, which explore to the limits of the protection collimator apertures. The only electrons that can pass through the safety dump dipoles must first pass through collimator PCPM2, thereby guaranteeing that beams that pass through the protection collimators will be bent by the permanent magnets into the safety dump. PCPM1 is a two-hole collimator that defines input apertures for both the operational dump line and the safety dump line (see Fig. 1). A powered muon spoiler is also shown in Fig. 2, which is not part of the safety dump system. The spoiler produces no magnet fields within its aperture and its most effective location, somewhere between PCPM1 and PCPM2, is not yet finalized.

Figure 2 also shows two stoppers (ST1 and ST2) inserted into the beamline. These two stoppers, in conjunction with the permanent magnet safety dump, prohibit electrons from entering the Front-End Enclosure (FEE) when it is in access. When the FEE is in a no-access state the ST1 and ST2 stoppers can be opened.

The tracking shown in Fig. 2 also includes the horizontal position dependence of the vertical dipole field as plotted in Fig. 3, which closely models the field roll-off of the existing FFTB permanent magnet dipoles. Figure 4 shows the elevation view of the safety dump trajectory. The electrons are not bent in the vertical plane by the safety dump, but the initial trajectory position and angle errors show that the electrons come close to the permanent magnet pole tips, which have been increased here to a 5.2-cm full height from their present FFTB value of 3.8 cm. This reduces the field from 0.430 T to 0.315 T (used in Fig. 2), assuming a linear scaling with gap height.

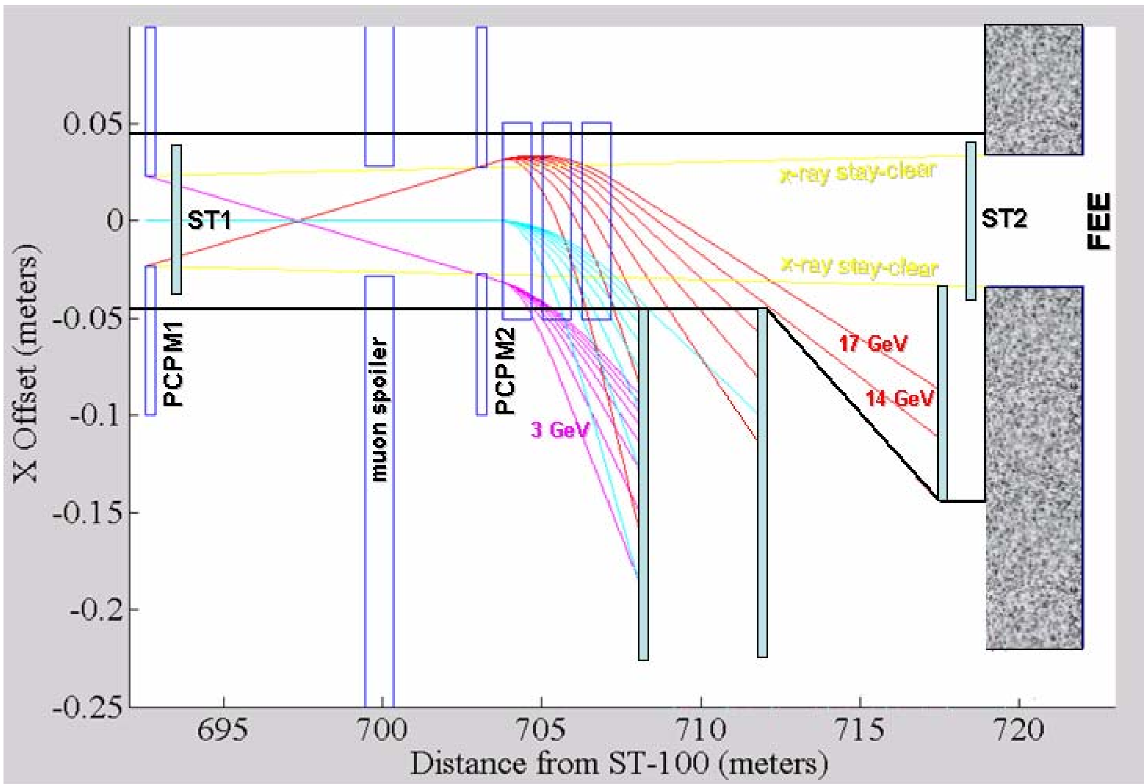

Figure 2. An array of beam energies (from 3 to 17 GeV in 2-GeV steps) and initial trajectory position and angle errors are plotted, showing that electrons that pass through the safety dump dipoles must first pass through collimator PCPM2, thereby guaranteeing that all electrons that pass through the protection collimators will be bent by the permanent magnets into the safety dump.

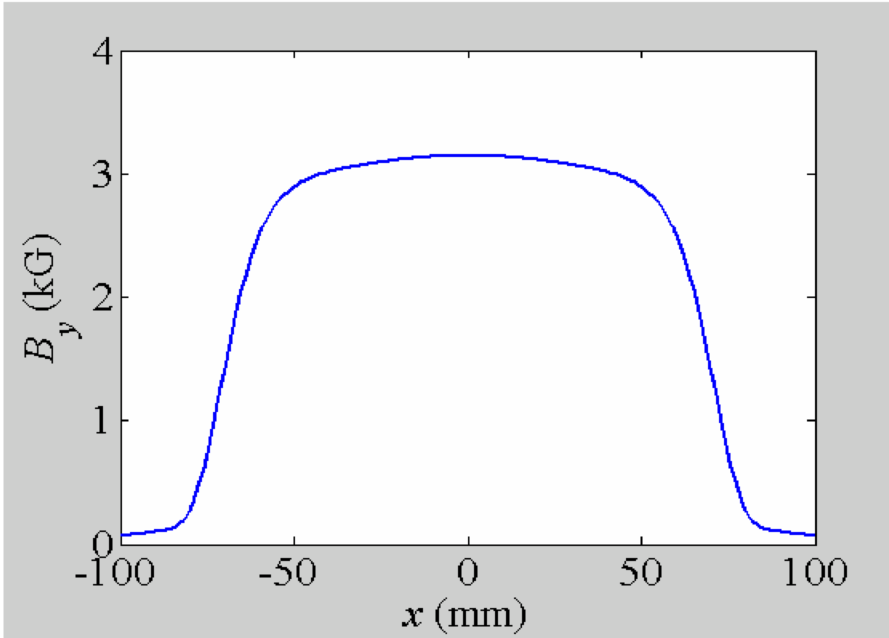

Figure 3. Horizontal position dependence of the vertical dipole field, which closely models the field roll-off of the existing FFTB permanent magnet dipoles magnets (gap height set to 5.2 cm here).

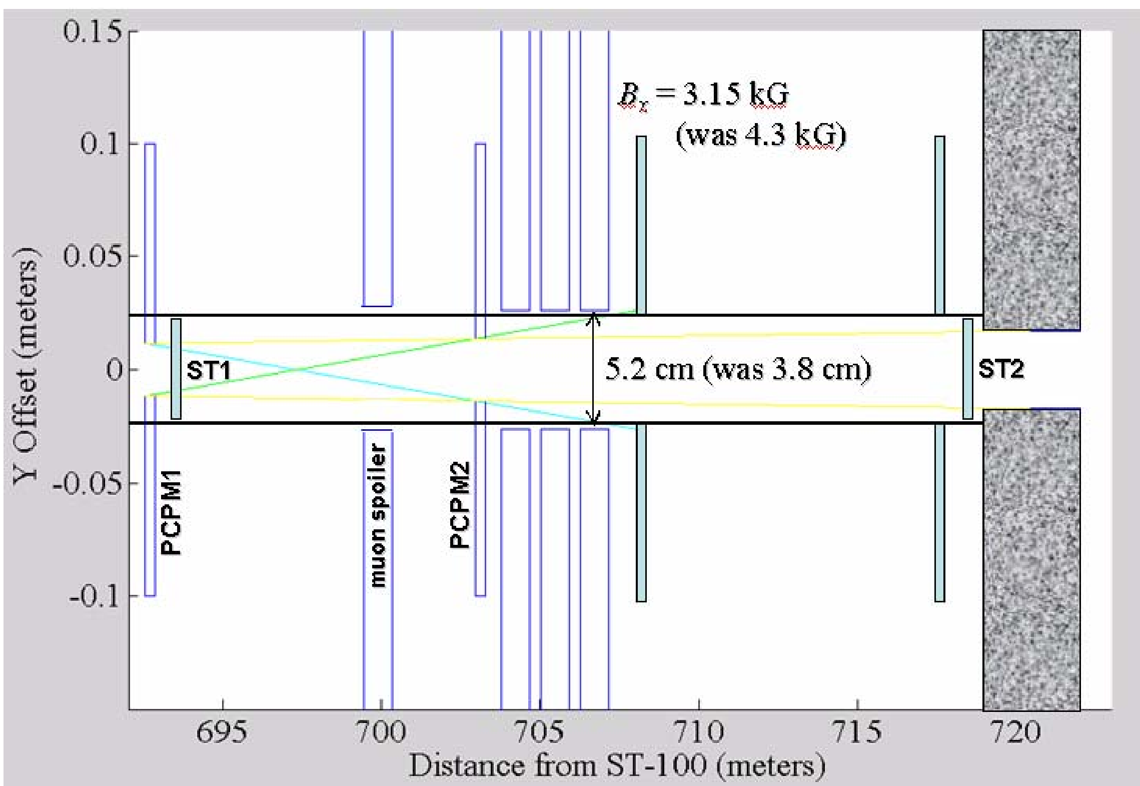

Figure 4. Elevation view of the safety dump trajectory. The electrons are not bent in the vertical plane by the permanent magnets. The worst-case initial trajectory position and angle errors show that the electrons can come close to the permanent magnet pole tips, which have been increased here to a 5.2-cm full height. This reduces the field to 0.315 T.

The Electron Safety Dump System will include the following components:

- 1 safety dump
- 1 operational dump
- 4 protection collimators (PCs)
- 6 burn-through monitors (BTMs)
- 10 beam containment protection ion chambers (BCS PICs)
- 4 beam containment flow switches.

Table 1: Electron Safety-Dump Parameters.

Parameter Description	**Symbol**	**Value**	**Unit**
Nominal operational energy range	E_o	4.3-13.6	GeV
Full energy range	E_f	3-17	GeV
Peak magnetic field of permanent magnets	B_{PM}	0.315	Tesla
Effective length of permanent magnets	L_{PM}	0.944	m
Full gap height of permanent magnets	g_{PM}	5.2	cm
Spacing between dipole magnets	Δz	30	cm
S-location of center of BXPM1*	S_{PM1}	704.228	m
S-location of center of BXPM2*	S_{PM2}	705.472	m
S-location of center of BXPM3*	S_{PM3}	706.715	m
Full aperture width/height of PCPM1	$\Delta x_1/\Delta y_1$	4.66/2.33	cm
Full aperture width/height of PCPM2	$\Delta x_2/\Delta y_2$	5.49/2.75	cm
S-location of center of PCPM1*	S_1	692.844	m
S-location of center of PCPM2*	S_2	703.256	m
Thickness (in beam direction) of PCPM1	Δz_1	30	cm
Thickness (in beam direction) of PCPM2	Δz_2	30	cm
S-location of entrance face of FEE wall*	S_{FEE}	719.000	m
Full aperture width/height of FEE wall	$\Delta x_{\mathrm{FEE}}/\Delta y_{\mathrm{FEE}}$	6.76/3.38	cm
Avg. power rating for operational dump	P_{dump}	5.0	kW

* In this coordinate system the undulator ends at $S = 646.965$ m

Check the LCLS Project website to verify that this is the correct version prior to use.