Document Approval:

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A.Batyuk (Nov 27, 2023 10:57 PST)

• Content/Format • Req ID's/Source ID's • Verif. Planning • SME Input, as appl

Reviewer: Marc Weibel– ES&H Manager   signature not required

• ES&H Content, as appl

Approver: Angelo Dragone, Detector Engineer

Angelo Dragone (Nov 27, 2023 11:07 PST)

• Complete/Accurate • SME Involvement • Actionable, as appl

Approver: Conny Hansson, LCLS Detector Department

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ConnyHansson (Dec 4, 2023 12:25 PST)

Verif. Planning • SME Input, as appl

Approver: Hong Bach, Quality Assurance Manager

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• General QA Provisions • Req's Validation/Verification, as appl

Approver: Ted Price or designee, Systems Engineer

Ted Price
Ted Price (Dec 1, 2023 15:48 PST)

• Clarity • Format • Req ID's/Traceability • Change Control, as appl

Approver: Scott DeBarger– Interim Project Chief Engineer

Scott DeBarger
Scott DeBarger (Dec 14, 2023 00:12 PST)

• Scope Alignment, Stakeholder/ SME Engagement

Approver: Eliazar Ortiz, System Manager

Eliazar Ortiz
Eliazar Ortiz (Nov 30, 2023 14:06 PST)

• Articulation • Meets Higher Level Expectations • Alt. CAM/SM Informed, as appl

Revision History

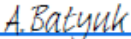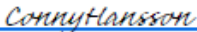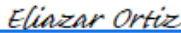| Revision	Date Released	Description of Change
R2	11/27/2023	Adjusted SFAD and LFAD well depth and noise requirements. • 4204: changed from 10 keV to 8 keV • 4205: change from 75 to 100 e- • 4104: changed from 10 keV to 8 keV • 4105: changed from 75 to 100 e- • 4108, 4110, 4112: Added comment referring to MFX Detector IRD • 4112: added lower bound of 5 mm Added requirement 4113 on LFAD working distance.
R1	5/30/2023	Removed sparsification requirement from SFAD.
R0	12/20/2020	Original Release

Table of Contents

1 Purpose

This Physics Requirements Document (PRD) identifies and outlines physics requirements that apply to the portion of the LCLS-II facility that is referenced in this document, and that must be addressed as part of the LCLS-II-HE project. From this information, the engineering team will formulate engineering requirements that provide the basis for hardware and software design, development, and integration. Thus, the PRD primarily focuses on performance criteria that can be traced back to top-level system/facility performance parameters. However, PRD preparation and approval also ensure that requirements can be properly interpreted at lower levels of specification, for purposes of accurate system developmental definition.

2 Scope

This PRD details the requirements for the MFX high-rate X-ray area detectors. Two detectors are required in MFX: a large area detector for capturing scattering/diffraction patterns and a smaller format area detector for collecting emission spectra. The listed parameters represent what is required at first light.

3 Acronyms

Acronym	Definition
IRD	Interface Requirements Document
LFAD	Large Format Area Detector
MFX	Macromolecular Femtosecond Crystallography Instrument
PRD	Physics Requirements Document
QE	Quantum Efficiency
SFAD	Small Format Area Detector

4 References

LCLSII-HE-PP-0224	Requirements Specification Preparatory Instruction
LCLSII-HE-1.4-PRD-0213	LCLS-II-HE MFX Instrument PRD
LCLSII-HE-1.4-IR-0879	LCLS-II-HE MFX Detectors IRD

5   Roles and Responsibilities

Alex Batyuk MFX Instrument Scientist	Defines requirements
Angelo Dragone Detector Engineer	Oversees the delivery of the requirements specified in this PRD
Conny Hansson LCLS Detector Department	Approves verification method

6   Requirements Definition

6.1   Smaller Format Area Detector (SFAD) for Emission Spectroscopy

Requirement #	Requirement	Comments	Verification Method	Parent Requirement	Verification Milestone
PRD0279.4201	The SFAD shall be designed for an energy sensitivity range between 4-12 keV	The goal is to achieve energy sensitivity up to 20keV on the SFAD.	Analysis Test	PRD0213.3318	
PRD0279.4202	The SFAD QE shall be >70% @ 12 keV	The goal is to achieve QE>70% @ 20 keV on the SFAD.	Analysis Test	PRD0213.3318	
PRD0279.4203	The SFAD frame-rate shall be > 5 kHz in full frame mode	The goal is to achieve a frame-rate ≥ 25 kHz in full frame mode.	Test	PRD0213.3318	
PRD0279.4204	The SFAD pixel full well shall be >10,000ph @ 8keV per pulse		Test	PRD0213.3318	
PRD0279.4205	The SFAD read-out noise shall be < 100e-		Test	PRD0213.3318	
PRD0279.4206	The SFAD sensitive area shall be ≥ 110kPix 40x40 mm^2		Inspection	PRD0213.3318	
PRD0279.4207	The SFAD pixel size shall be ≤ 100 μm x 100 μm		Inspection	PRD0213.3318	
PRD0279.4208	The SFAD cabling and cooling length shall be ≥ 2 m		Inspection	PRD0213.3318	

Requirement #	Requirement	Comments	Verification Method	Parent Requirement	Verification Milestone
PRD0279.4209	The SFAD physical package envelope [mm^3] (WxLxD) shall be < 50 x 50 x 200		Inspection	PRD0213.3318	

6.2 Large Format Area Detector (LFAD) for Scattering/Diffraction

Requirement #	Requirement	Comments	Verification Method	Parent Requirement	Verification Milestone
PRD0279.4101	The LFAD shall be designed for an energy sensitivity range between 4-12 keV	The goal is to achieve sensitivity up to 20keV on the LFAD.	Analysis Test	PRD0213.3318	
PRD0279.4102	The LFAD QE shall be >70% @ 12 keV	The goal is to achieve QE>70% @ 20 keV on the LFAD.	Analysis Test	PRD0213.3318	
PRD0279.4103	The LFAD frame-rate shall be > 5 kHz in full frame mode	The goal is to achieve a frame-rate≥ 25 kHz in full frame mode.	Test	PRD0213.3318	
PRD0279.4104	The LFAD pixel full well shall be >10,000ph @ 8keV per pulse		Test	PRD0213.3318	
PRD0279.4105	The LFAD read-out noise shall be < 100 e-		Test	PRD0213.3318	
PRD0279.4106	The LFAD sensitive area shall be ≥ 8MPix	The goal is to achieve a sensitive area ≥ 16MPix	Inspection	PRD0213.3318	
PRD0279.4107	The LFAD pixel size shall be ≤ 100 μm x 100 μm		Inspection	PRD0213.3318	
PRD0279.4108	The LFAD cabling and cooling length shall be ≥ 2 m	See MFX Detector IRD for more detail.	Inspection	PRD0213.3318	
PRD0279.4110	The LFAD shall mount onto MFX detector mover table	See MFX Detector IRD for more detail.	Inspection	PRD0213.3318	
PRD0279.4111	The LFAD mass shall be ≤ 200 kg		Inspection	PRD0213.3318	

Requirement #	Requirement	Comments	Verification Method	Parent Requirement	Verification Milestone
PRD0279.4112	The LFAD shall have a ~5-6 mm through beam hole in the center	See MFX Detector IRD for more detail.	Inspection	PRD0213.3318	
PRD0279.4113	The working distance of the LFAD shall be 100mm-200mm downstream of the IP.		Inspection		