LCLS 1 Linac Energy Increase
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Goal: Increase maximum beam energy from 17.5 GeV to 24.75 GeV; increase maximum photon energy from 13.6 keV to 27.2 keV

How: Use LI00-LI10 klystrons/SLEDs/Modulators/VVSs(?) to increase the maximum energy available from the LCLS 1 LI20-LI30 linac

Question: Are the users interested in such an upgrade? An alternative view is to double the installed rf power in L3 for reliable operations at the Se K-edge at 12.66 keV (~16.9 GeV *need to check numbers*) so that L3 energy 5-15 GeV increases to 5-19 GeV

WAG Estimated Cost: ~50M$ (1M$ per new station; 48 new stations in LI25-LI30); likely significant savings by dropping down to 60Hz for higher energy operation (need to get Facilities estimates for VVS and water)

Issues to be addressed

(1) Power and cooling system requirements
(2) Present installed capacities
(3) Proposed Upgrade Overview
(4) Linac Magnet System Capabilities and Upgrades (as needed)
(5) Klys/Mod/VVS Refurbishment Issues, including EEIP and Electrical Safety Code compliance
(6) Cooling System Upgrades, including cooling tower, pump, and water piping requirements
(7) Detail new rf system layout (L1, L2, L3)
(8) Control system issues (more of the same?)
(9) Straw proposal for upgrade, including full installation and piecemeal upgrade and 60 Hz operation to save on power and cooling requirements
(10) Estimated costs and schedule

Questions

(1) FEL performance expectations (i.e. emittance requirements at higher beam energy; beam jitter due to increased number of tubes)
(2) Synchrotron radiations issues at higher beam energy
(3) Potential Undulator issues (radiation damage, electron beam optics)
(4) Dark current at higher gradients
(5) RF break down at higher gradients
(6) Photon beamline issues for increased photon energies and background radiation

Additional Issues Needing Attention

(1) Accelerator Safety Envelope for increased beam energy and beam power
(2) Downstream magnet strength and power supply requirements (LTU, BSY, Undulator, Dumpline)
(3) Any electron beam dump questions

Additional Help Needed for this Study
RF, Electrical, Facility Engineering for design and costing

Proposed Feasibility Test

Replumbing a single station to power just two sections and then run it up to see if there are any break down issues in the dlwg, loads, or rf distribution. A test should be able to be done rather quickly with the caveat that there may be issues from the waveguide vent and if there are break down issues, can these be processed away. The test and processing can all be done on standby time if care is taken to not gas up the adjacent stations.

Half power test: Reduce VVS voltage to 455V (from 600V) and check for stable klystron operation (as well as reduction of output power to ½).

Issues to be addressed

(1) Power and cooling system requirements:

Power

Doubling of VVS from 1750 kVA/sector pair to 3500 kVA per sector pair
(45kW*16*2(efficiency) = 1440kW ➔ 45kW*32*2(efficiency)=2880 kW)

Water

Doubling of Klystron Water systems from 360 gpm to 720 gpm (need to flow) per 3 sectors; $\Delta T = 35^{o}F$

Increase ΔT for DLWG and Rectangular Waveguide

Cooling Tower 1202

11 MW ➔ 18 MW

(2) Present installed capacities:

Power

1750 kVA per VVS; 2 sectors per VVS

Water

360 gpm, $\Delta T = 35^{o}F$; 3 sectors per system for Klystron Water Systems

480 gpm, $\Delta T = 4^{o}F$; 2 sectors per system for Klystron Water Systems

150 gpm, $\Delta T = 2^{o}F$; 2 sectors per system for Waveguide Water Systems

Cooling Tower 1202

11MW

(3) Proposed Upgrade Overview

Move LI00-KI10 klystrons/modulators/VVS to LI21-LI30; refurbish as indicated, including requisite code compliance

Increase LI21-LI30 12.5 kV electrical distribution using existing lines that run to LI00-LI10 (may be in conflict with LCLS 2 planning)

Increase LI20-LI30 klystron cooling water system capacity; increase LI20-LI30 ΔT for DLWG and Rectangular Waveguide systems for a factor of 2 (4^{o} ➔ 8^{o} for DLWG; x^{o} ➔ y^{o} for RWG)

Increase Cooling Tower 1202 capacity by a factor of 2.5/1.5 (=1.667)

Controls for LI20-LI30 upgraded systems

Additional linac alcoves for VVS and cooling water pumps as needed

Notes:
Costs at present:

PEM-modulator upgrades:	100k$ per unit (CB)
Controls Upgrades:	70k$ per unit (nodes of 4 units) (DvW)
Mech Work:	73.5k$ per unit (DK: 8/25/2014)
Facilities Work:	$5M per VVS (CaJ: 9/9/2014: ~$2M hardware + install)

Each new klystron adds ~90 MeV acceleration
Each new klystron needs ~90 kW of 600V from VVS
Each new klystron needs ~50kW worth of cooling water

Can think about 60 Hz energy upgrade option: can use existing VVSs; no 12.5 kV nor klystron cooling water upgrades necessary; can configure so that 120 Hz running at existing klystron complement is retained

Present L3 maxes out at about 10.3 GeV so max E_γ ~10keV
L3 energy up grade takes beam to 19.5 GeV; E_γ = 17 keV for L2 = 5 GeV
L3 energy up grade takes beam to 21.2 GeV; E_γ = 20 keV for L2 = 6.7 GeV

Some stations are derated so as to avoid radiation generation from the SLEDs; these need to be identified; lead shielding can be installed

Tantawi may have an improved efficiency SLED design; this needs investigation in terms of performance and cost (~100k$ per unit as per Burkhart; EGAIN goes from 1.4→1.85)

Present PEM modulator refurbishment costs is ~100k$ per tube

VV13 install costs were ~250k$ including full cable plant for 16 klystrons (need to confirm and understand if this is correct)

Question: are klystrons stable if run at ½ power? Should make a test (Vmod=0.5^0.4*Vo=0.7579*350kV=265kV; $V_{ref1/2}$=0.7579*120V=90.94V)

Still need Controls, Facilities, and Mechanical discussions and estimates:

Update 8/04/2014: Have been in contact with Burkhart (RFARED); Bobczynski, et al (Facilities); Murphy (Controls); DeBarger (Mech); Seeman (LI00-LI10 Removal). Need to write a PRD as well as an ICD-parts list for items to be salvaged. Meeting with Tantawi this am to discuss Tantawi's improved SLED systems.

Will need to remeet with everyone to agree of ballpark estimates.

Update 8/8/2014: Controls estimate comes to $70k per station (in addition to PEM controls); ICD packages come is nodes of 4 klystrons/tube. Tantawi's improved SLED is still in investigation stages with not designs nor agreed upon solution. Expects to have concept by end of September, 2014. I suggested that he consider prototyping a unit at s-band and installing in FACET (perhaps in LCLS 1) for a full power performance and lifetime test. Brain stormed with D. Kharakh and came up with ~70K$ per station for mechanical work (demote, install, including waveguide work and plumbing, vacuum, instrument technician). Will meet again on Monday to firm up request for mechanical estimate

Update 8/10/2014: Mech working estimate of $100k per station (DK and SdB)

Update 8/25/2014: DK mechanical estimate of 73.5k per station, loaded

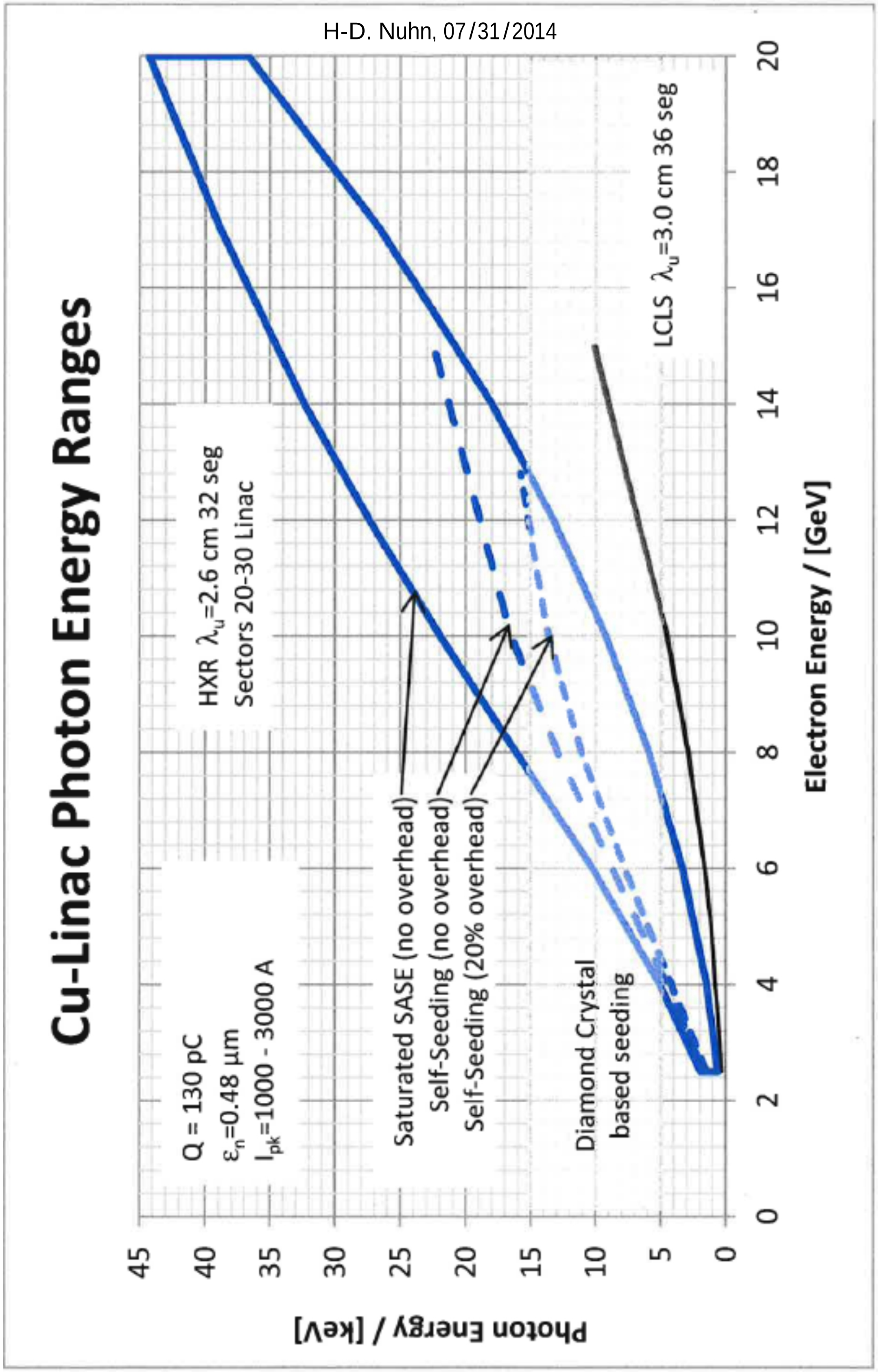
Dark Current: E-field to capture from rest is Ec=pi*mc2/qlrf=15.289MV/m

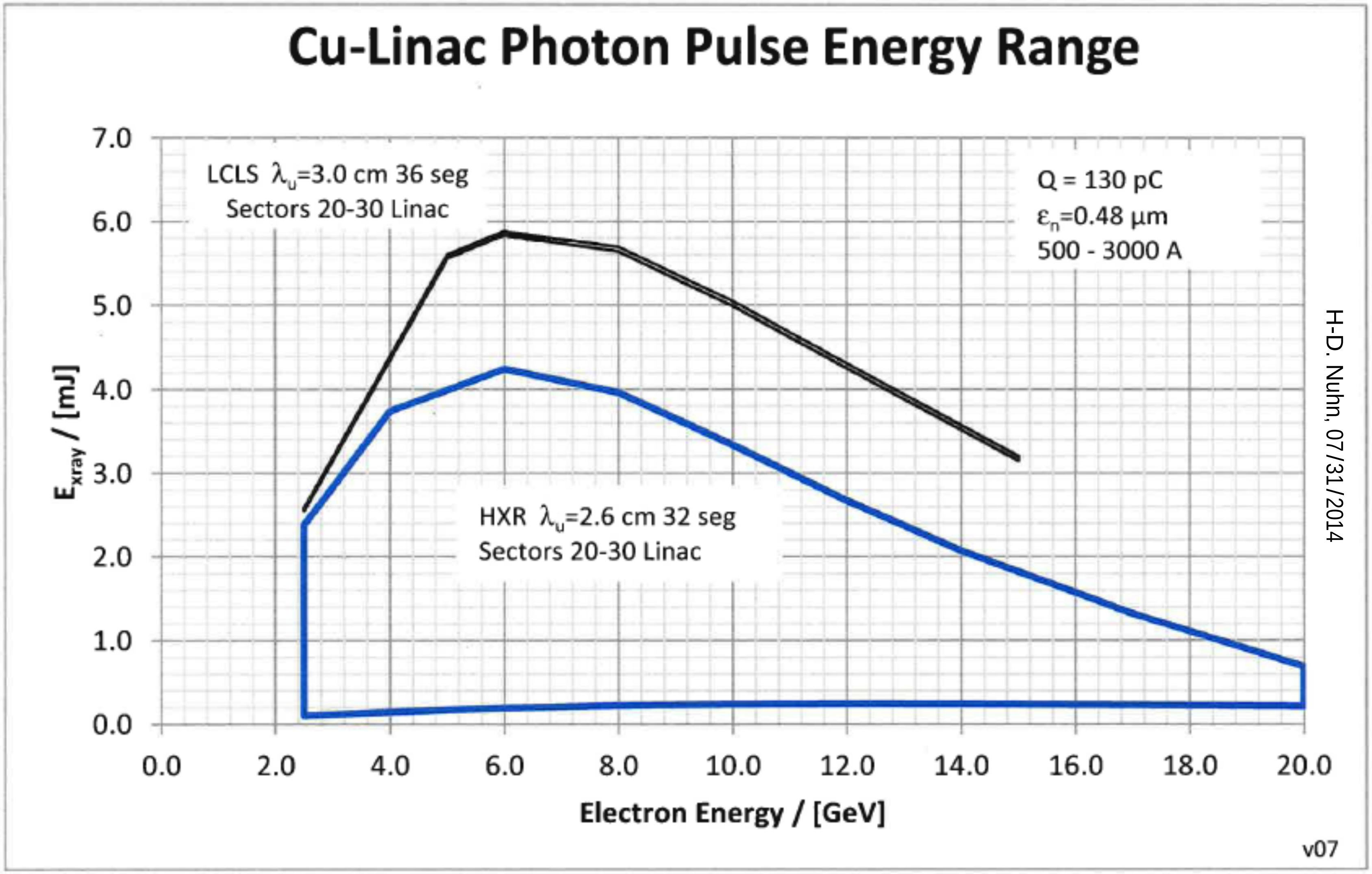
SLAC Blue Book says selection of gradient was to what s-band acccelerators operated at at time of construction: 4.5MV/foot; table indicates maximum achieved gradient to date (circa 1964) was 23MV/m

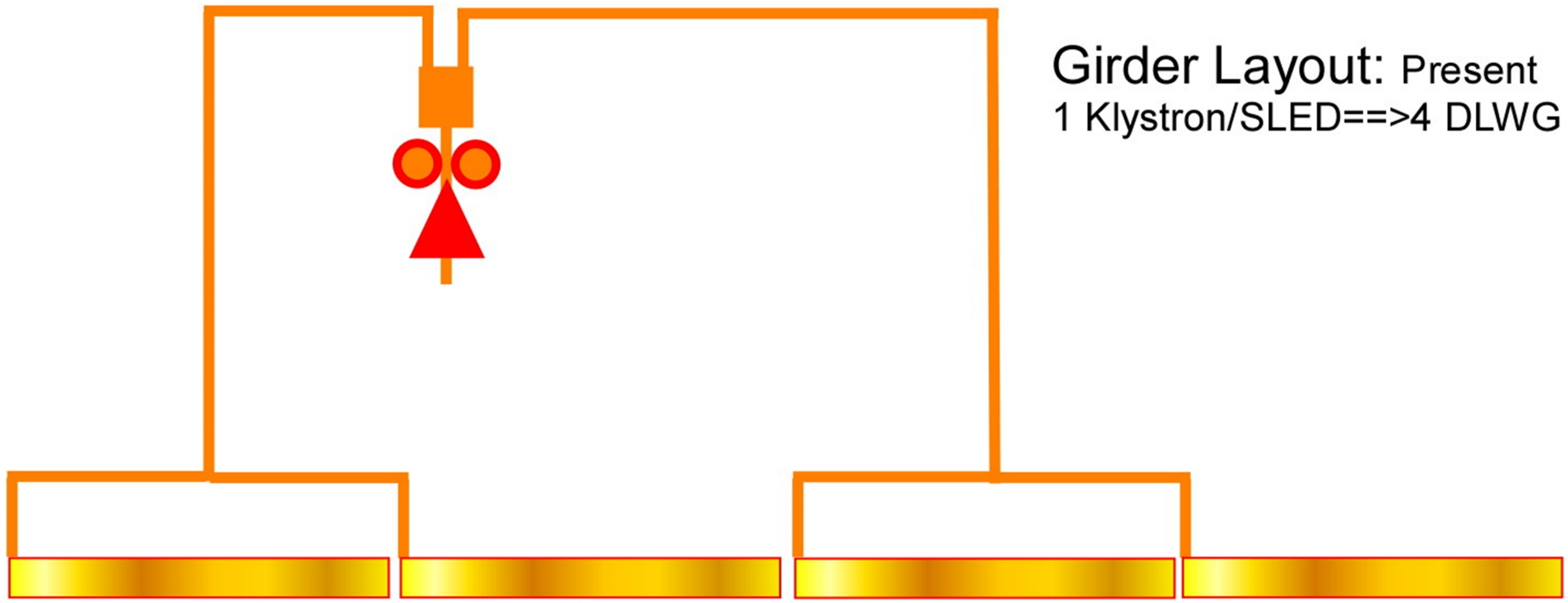
Anatoly Krasnykh says loads originally sized for 2MW peak power; presently running at about 20 MW peak power into loads; doubling rf brings high power load to 37MW for 60 MW tube

Cezary Jach says better option for VVS is to replace existing systems with new systems rated at 3.5 MVA in same footprint; avoids need for new alcoves; relocating upstream gear not an obvious fit do to left-rignt asymmetry of equipment, relocated stuff will push out into roadway. Hardware for upgrade is ~$1.4-2M; guesstimate factor of about 2.5 for installation and management.

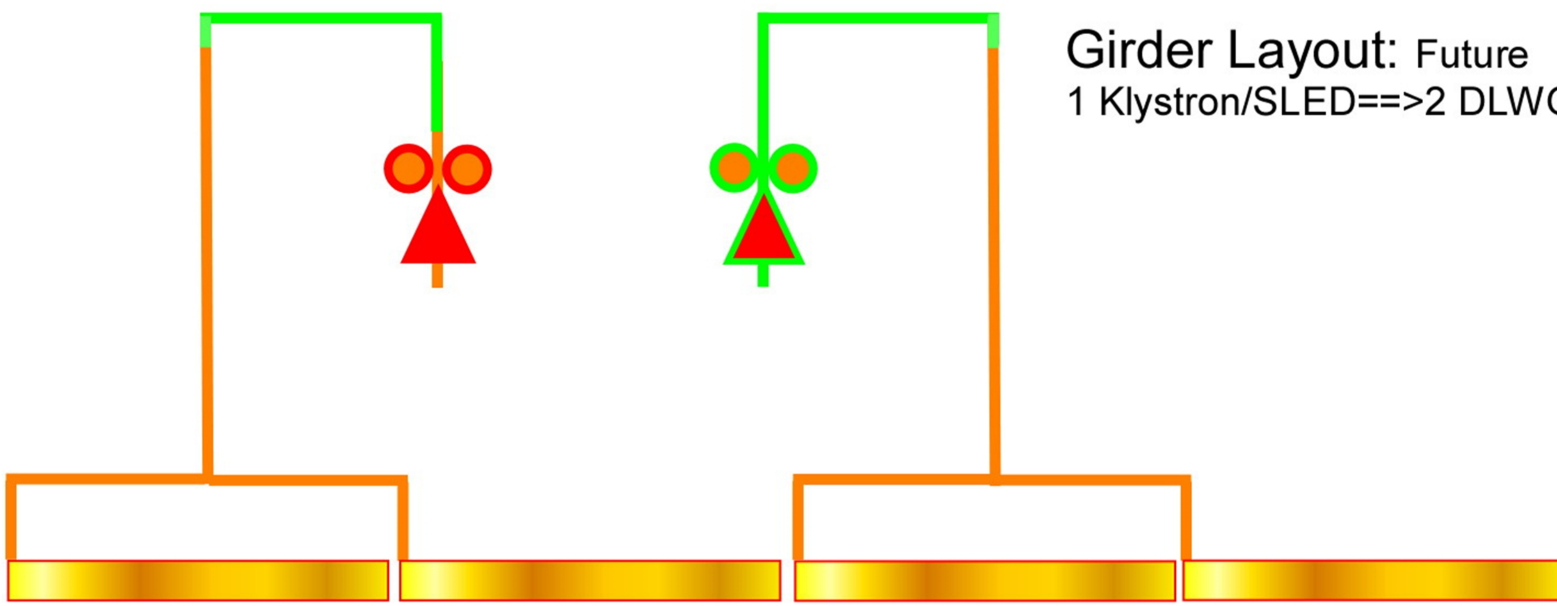
Not finding much regarding the need for higher energy photons; have not found a CDR or PreCDR for LANL MARIE which would have a science case argument. Link to MARIE provides some idease but nothing in depth: http://www.lanl.gov/science-innovation/capabilities/materials-science/marie/_assets/docs/70th-talk.pdf


H-D. Nuhn, 07/31/2014
Cu-Linac Photon Energy Ranges
Q = 130 pC
εn=0.48 µm
Ipk=1000 - 3000 A
HXR λu=2.6 cm 32 seg
Sectors 20-30 Linac
Saturated SASE (no overhead)
Self-Seeding (no overhead)
Self-Seeding (20% overhead)
Diamond Crystal
based seeding
LCLS λu=3.0 cm 36 seg
Electron Energy / [GeV]
Photon Energy / [keV]
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35
40
45


Cu-Linac Photon Pulse Energy Range
LCLS λ_u=3.0 cm 36 seg
Sectors 20-30 Linac
Q = 130 pC
ε_n=0.48 µm
500 - 3000 A
HXR λ_u=2.6 cm 32 seg
Sectors 20-30 Linac
E_{xray} / [mJ]
Electron Energy / [GeV]
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
v07
H-D. Nuhn, 07/31/2014



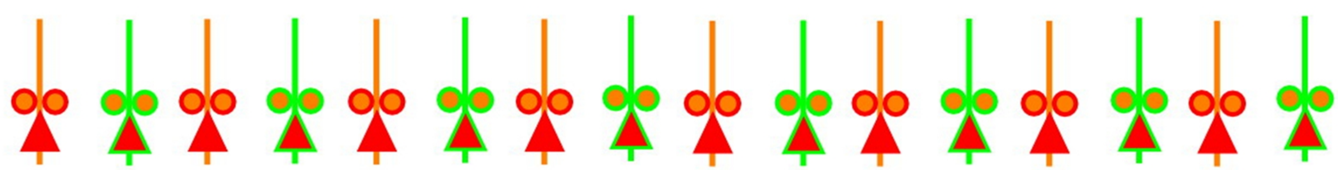
Girder Layout: Present
1 Klystron/SLED==>4 DLWG



Girder Layout: Future
1 Klystron/SLED==>2 DLWG

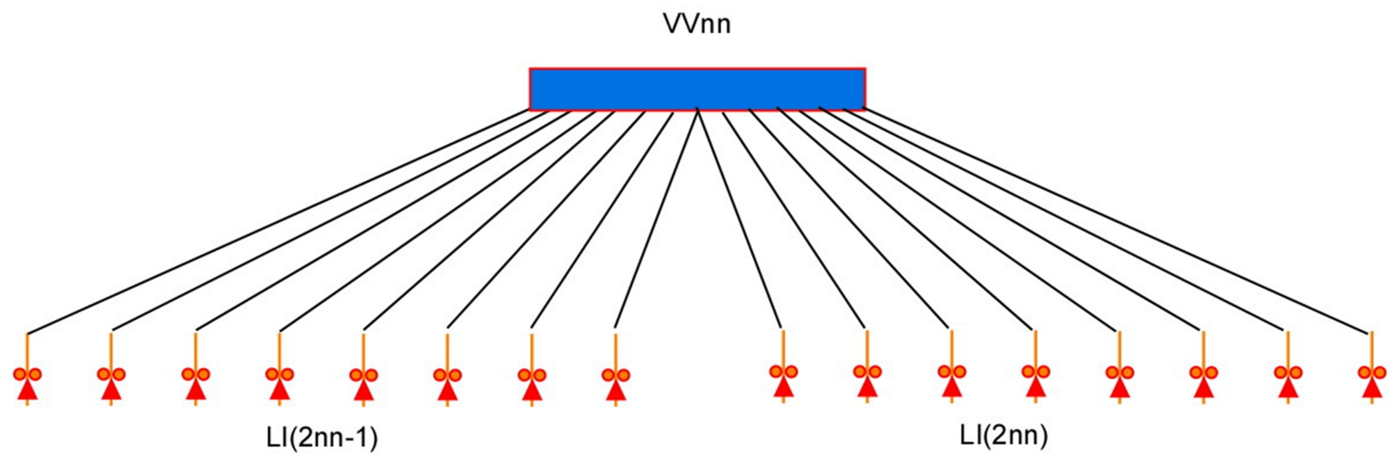
Sector Layout: Present
8 Klystrons per 101.6 m Sector

Sector Layout: Future
16 Klystrons per 101.6 m Sector



VVS Layout: Present

1 VVS per 16 Klystrons in 2-101.6 m Sectors



VVS Layout: Future

2 VVS per 32 Klystrons in 2-101.6 m Sectors