
Plans for *LCLS II*

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Presented at the

Joint DESY and University of Hamburg
Accelerator Physics Seminar

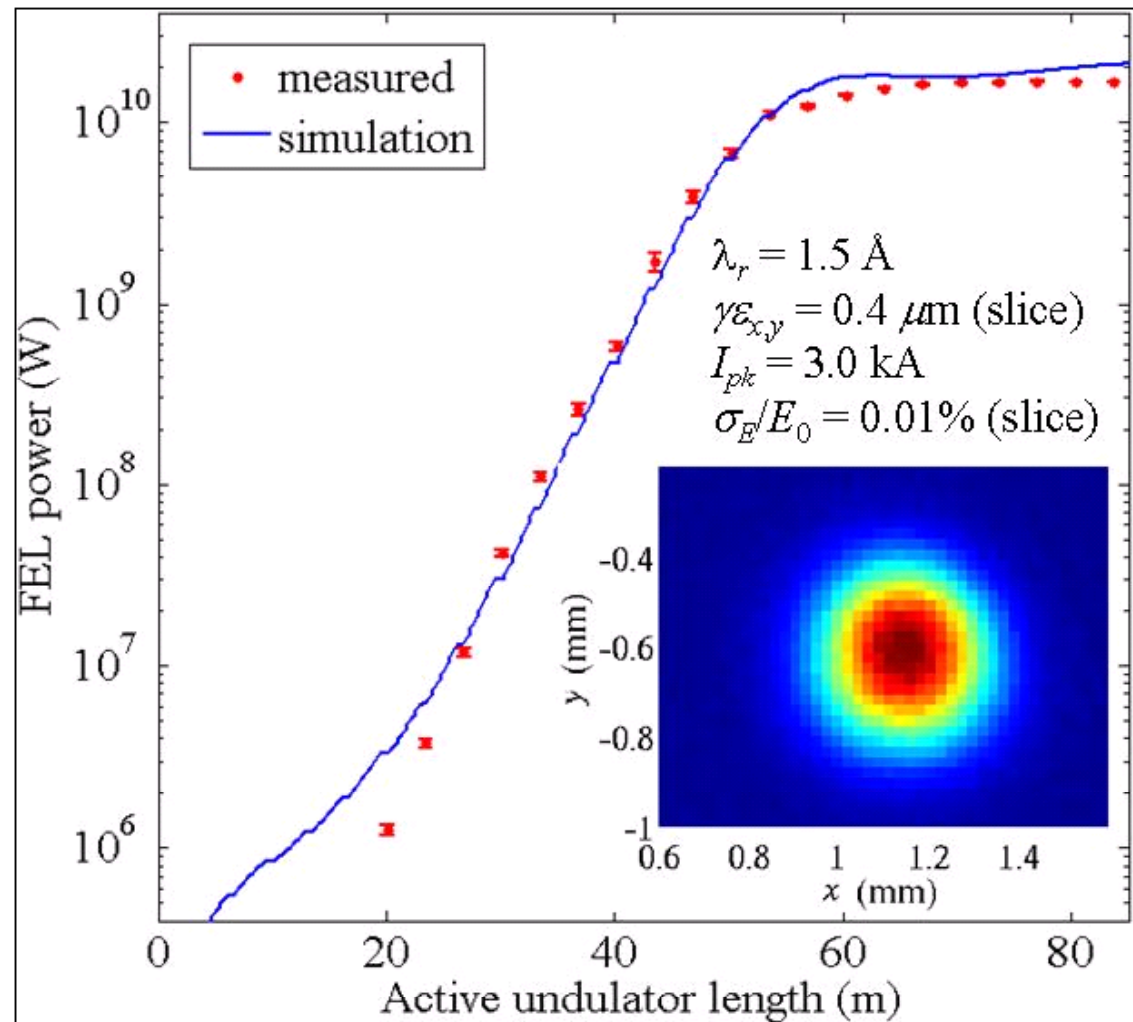


Tuesday, June 15, 2010



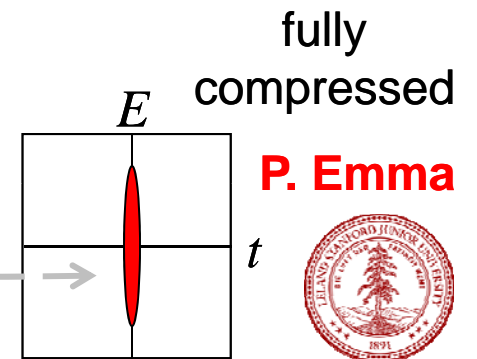
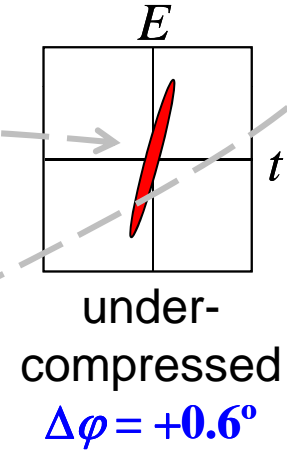
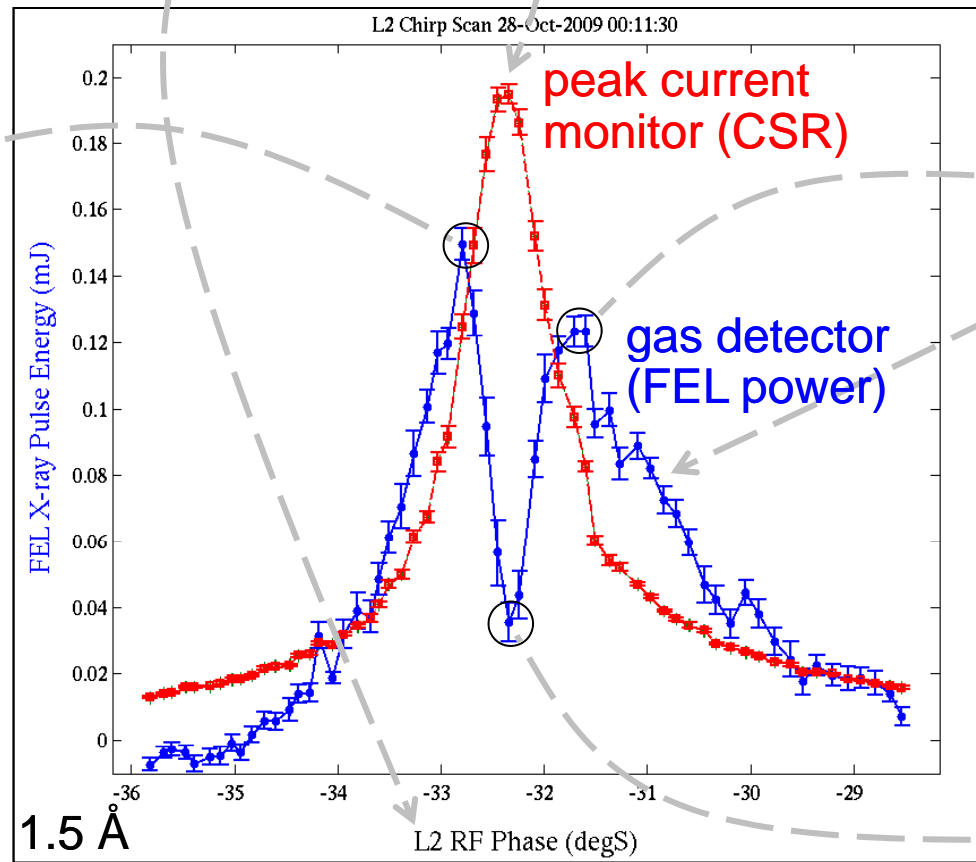
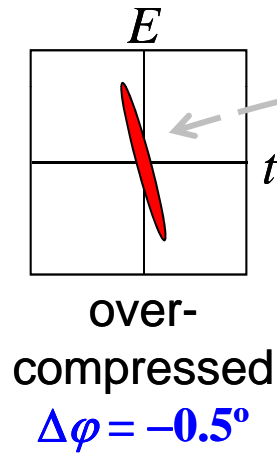
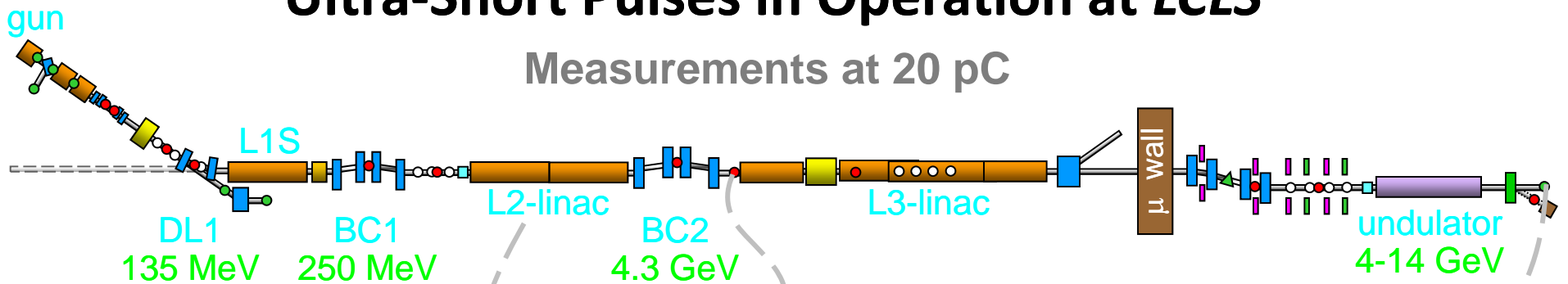
1.5-Å FEL Saturation at 65 m (of 112 m)

This success motivates an extension of the capacity, capabilities, and quality of this revolutionary new light source.



Ultra-Short Pulses in Operation at LCLS

Measurements at 20 pC



Ultra-Short X-ray Pulse Simulations Suggest <10 fs FWHM

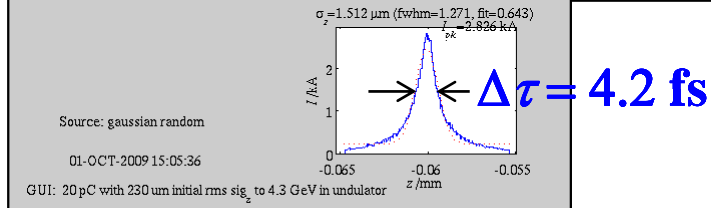
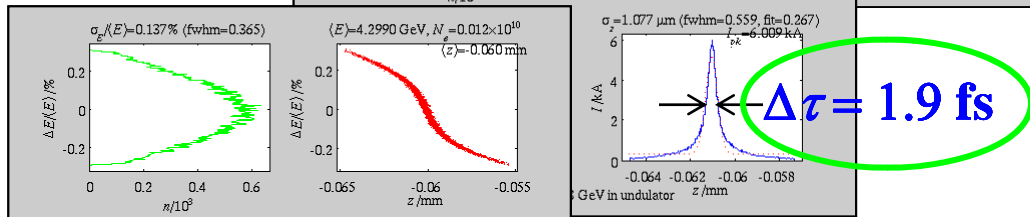
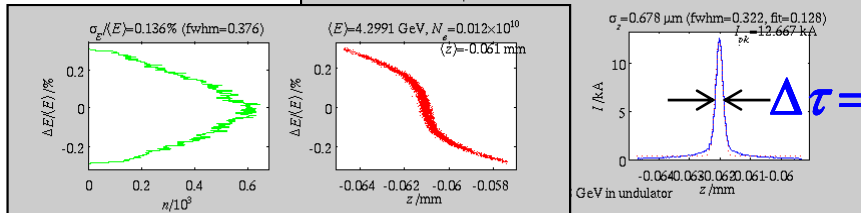
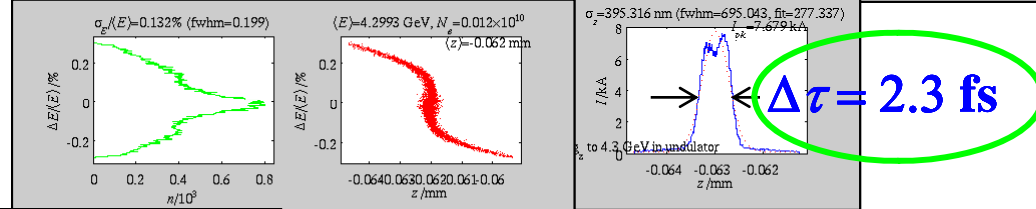
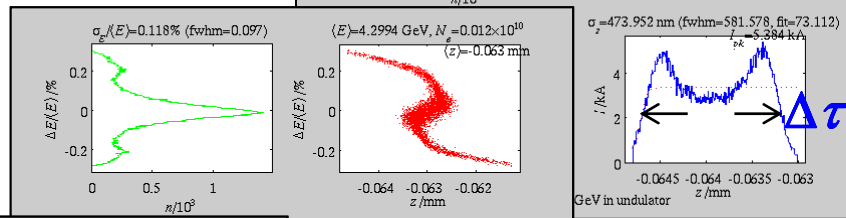
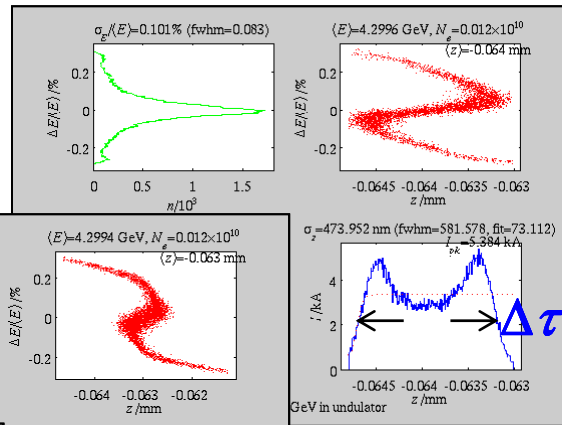
$\Delta\phi = +1^\circ$

$\Delta\phi = +0.5^\circ$

$\Delta\phi = 0^\circ$

$\Delta\phi = -0.5^\circ$

$\Delta\phi = -1^\circ$



P. Emma

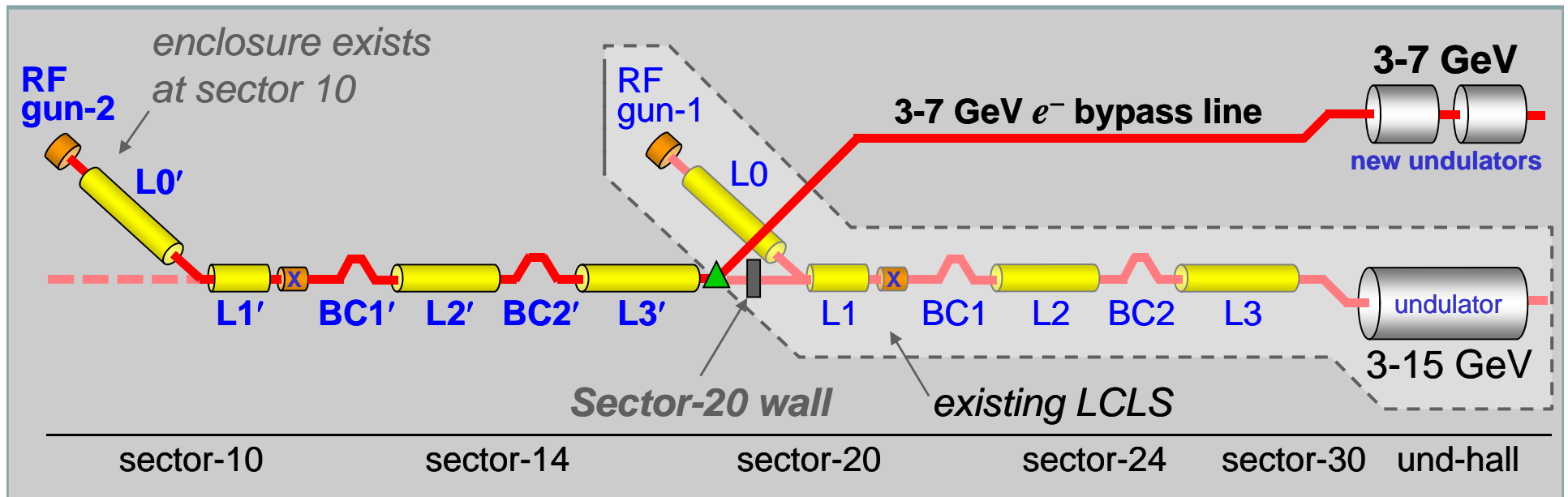
X-ray pulse duration should be <10 fs (FWHM), but no measurement possible yet

...now delivered to users

- 20 pC bunch charge
- 3 keV initial rms slice energy spread
- 0.23-mm initial rms bunch length



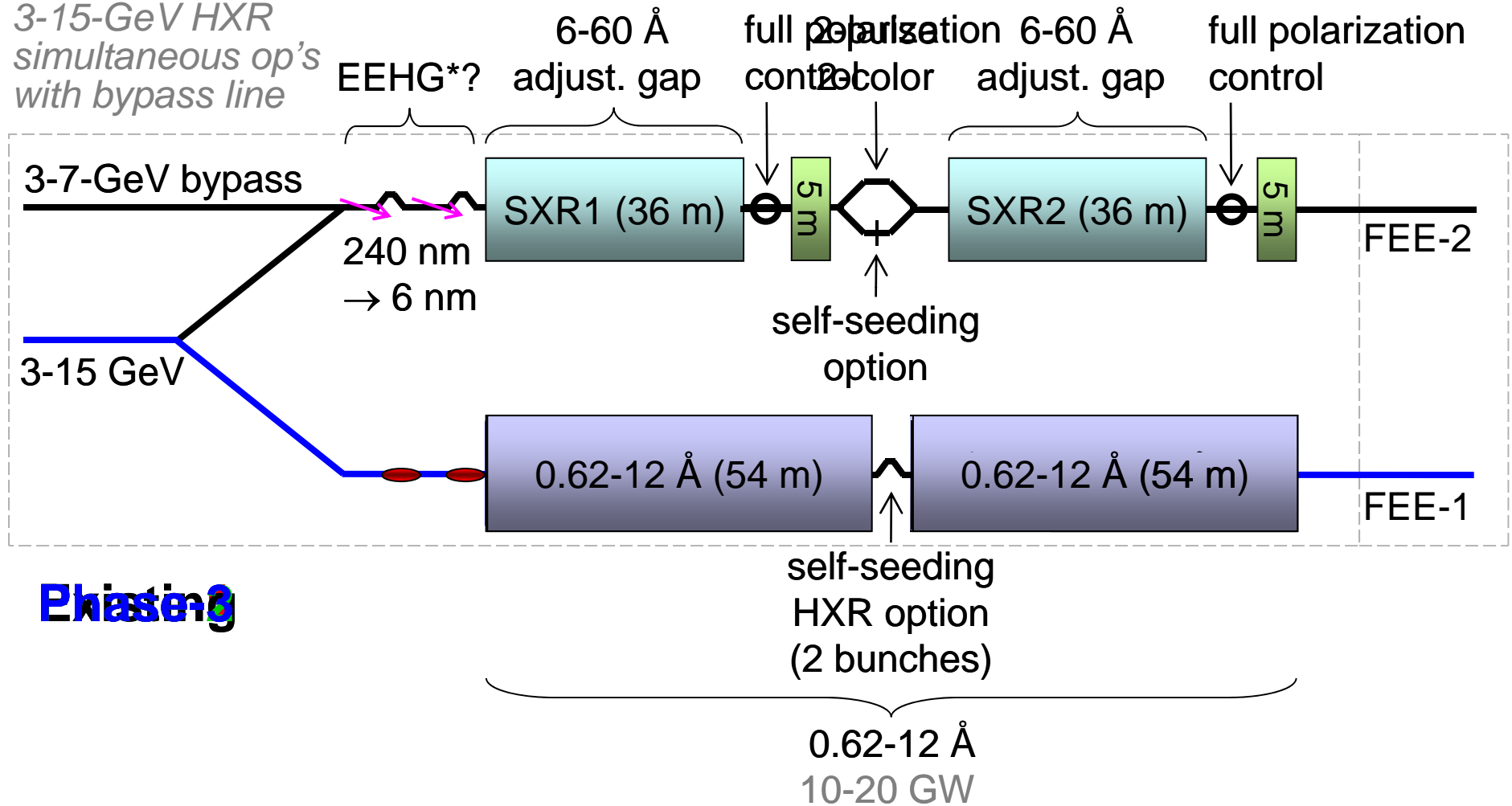
LCLS-II: New Injector & Accelerator



- Use 2nd km of SLAC linac (sector-10 to 20)
- 3-7 GeV energy (no SLED) allows possible 360-Hz beam rate
- 2nd injector, linac, & bypass line allows 2+ independent FELs serving 2 experiments simultaneously with flexible parameters
- Combining beams allows x-ray probe with decoupled wavelengths, pulse width, energy, and timing
- Preserves possibility for up to 30 GeV (and still one more km!)

Phased Enhancement Plan for *LCLS-II* FELs

3-7-GeV SXR and
3-15-GeV HXR
simultaneous op's
with bypass line



Phasing



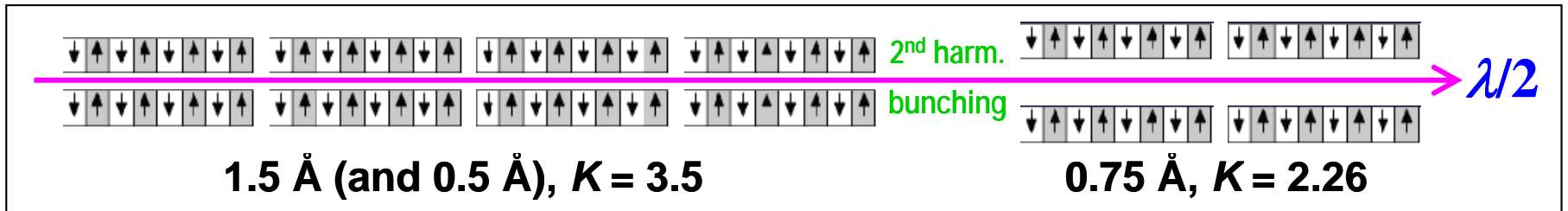
No civil construction. Uses existing beam energy and quality.

* G. Stupakov, Phys. Rev. Lett. **102**, 074801 (2009)



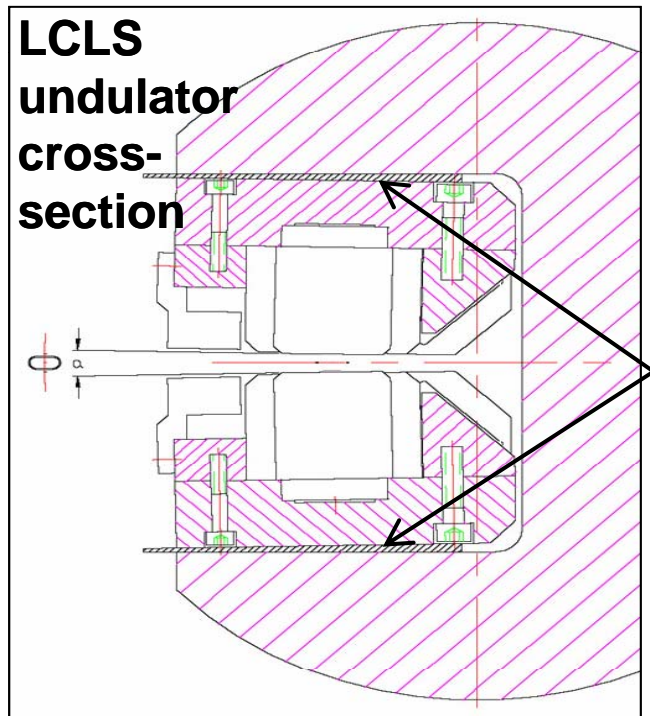
Fast Path to Producing FEL 2nd Harmonic

16 keV = 0.75 Å (up to 20 keV at 15 GeV)

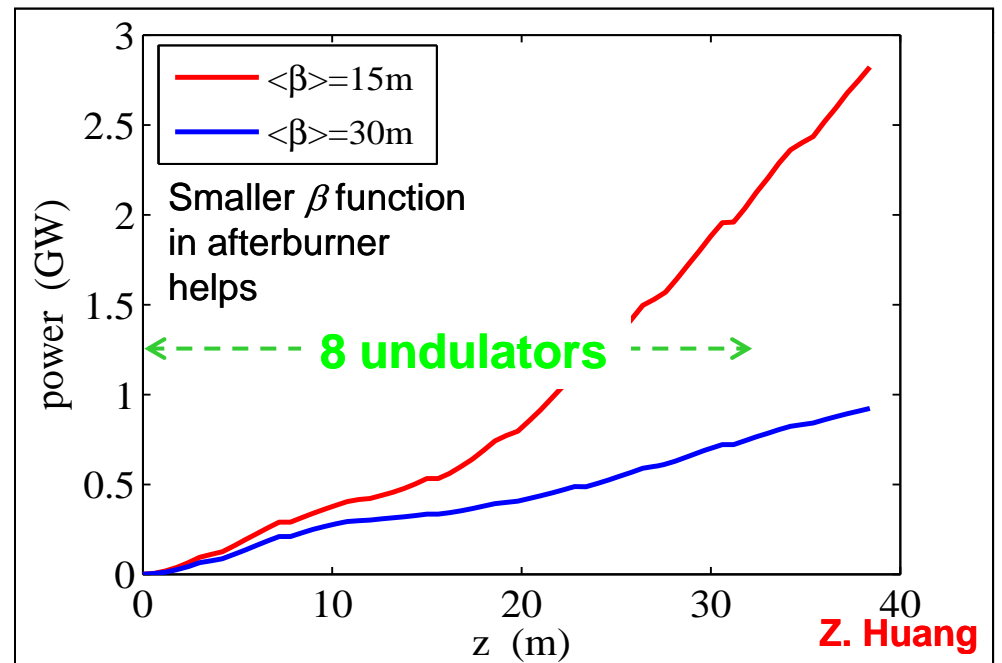


existing LCLS undulator

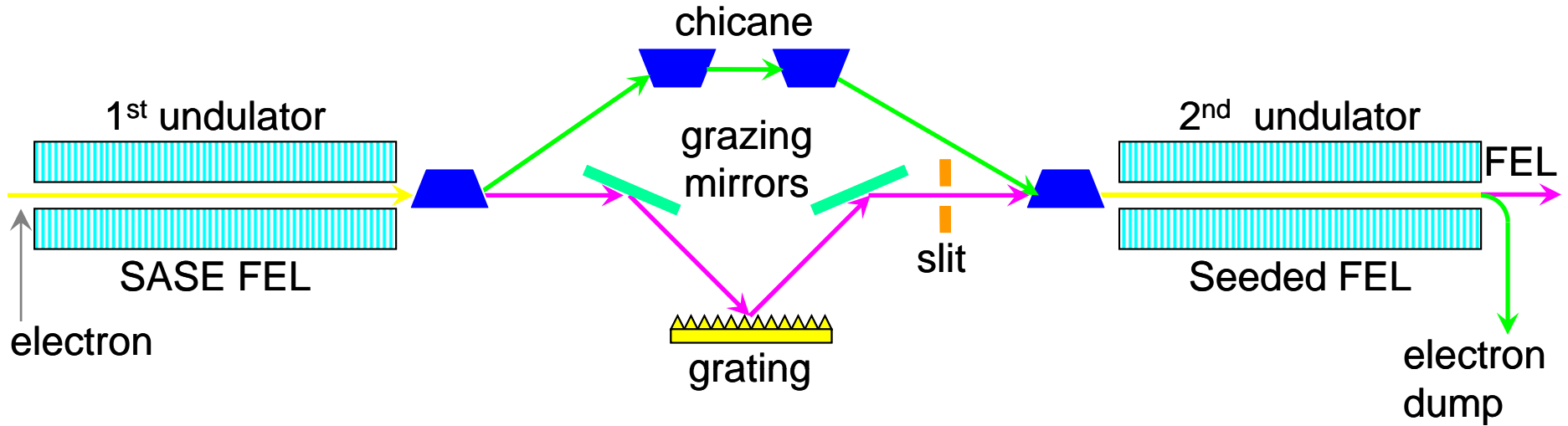
2nd harmonic after-burner



Replace shims for last 8-10 undulators (of 33)

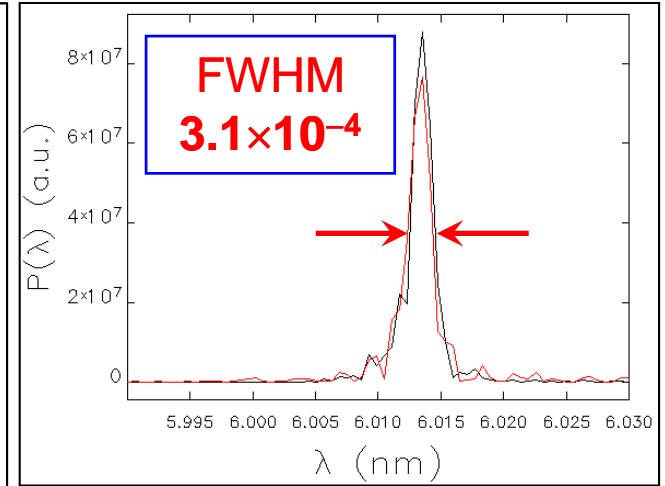
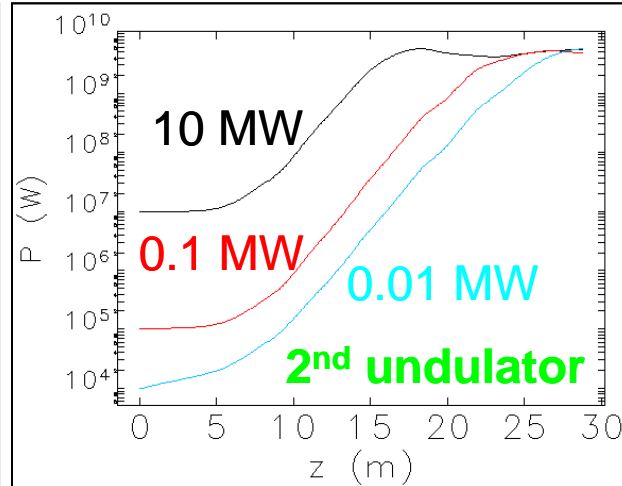
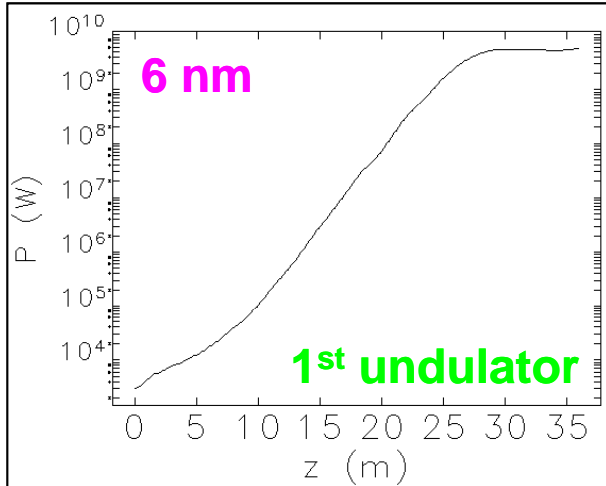


Self-Seeded FEL



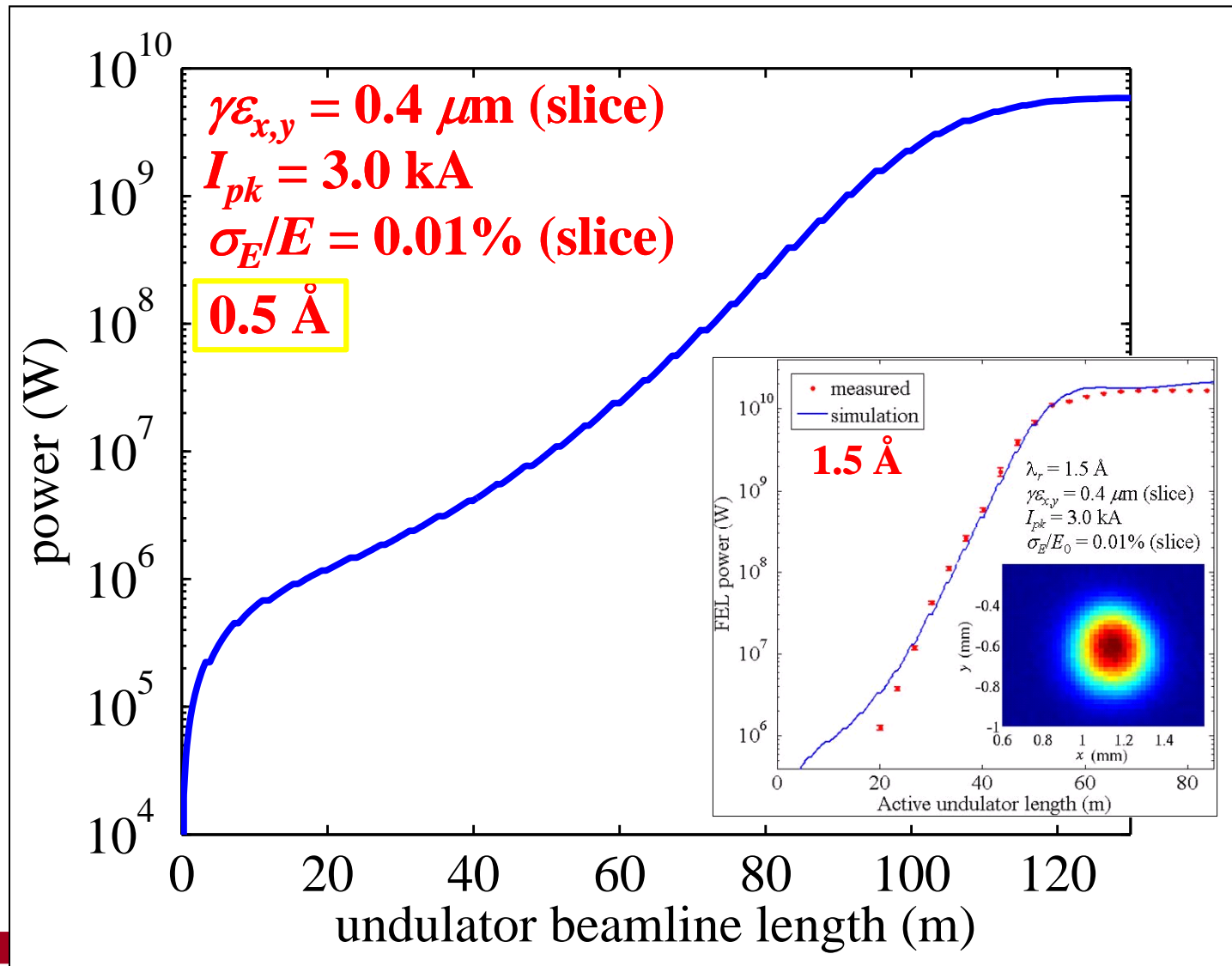
FEL spectrum at ~26 m in 2nd undulator for seed of 0.1 MW (black) and 0.01 MW (red)

J. Wu



LCLS Beam Supports 25-keV (0.5 Å) FEL at 14 GeV

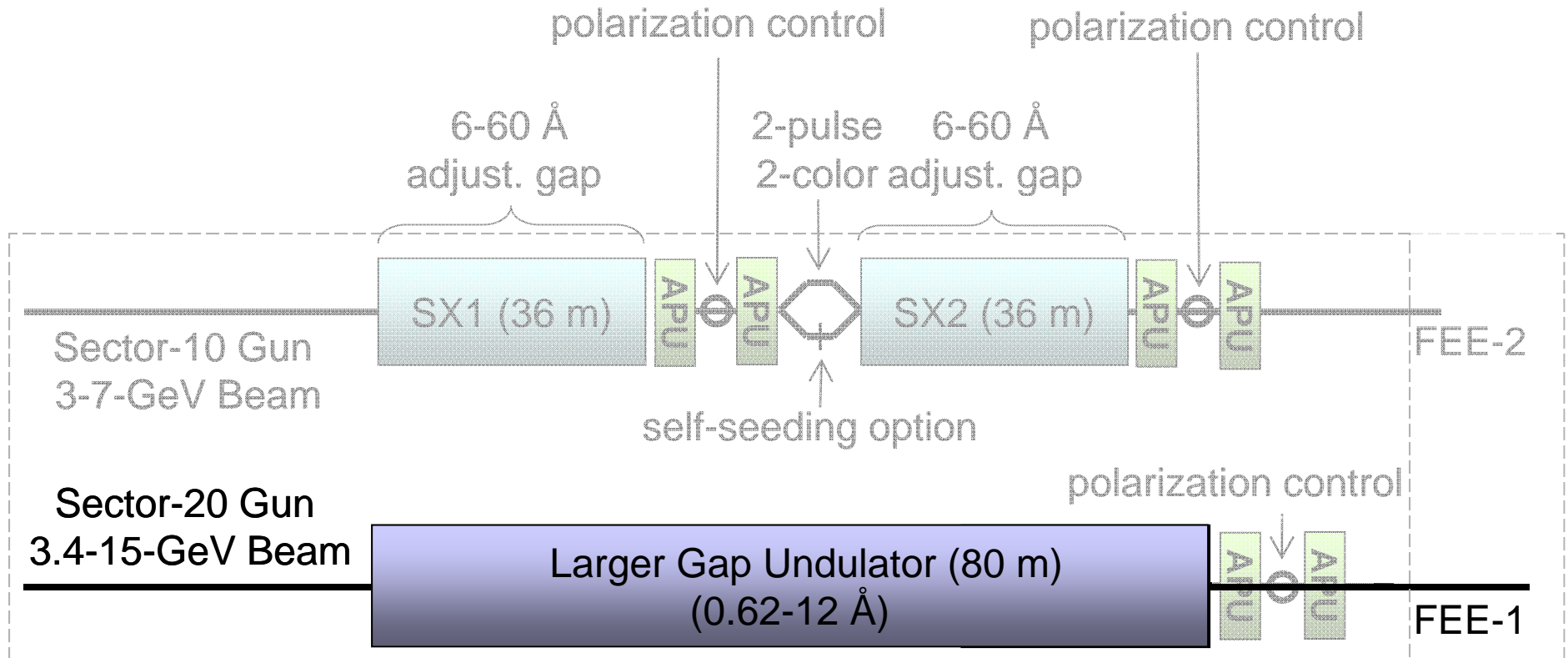
increase undulator gap further



**The next 6 slides will
graphically outline 6 *LCLS-II*
operating modes...**

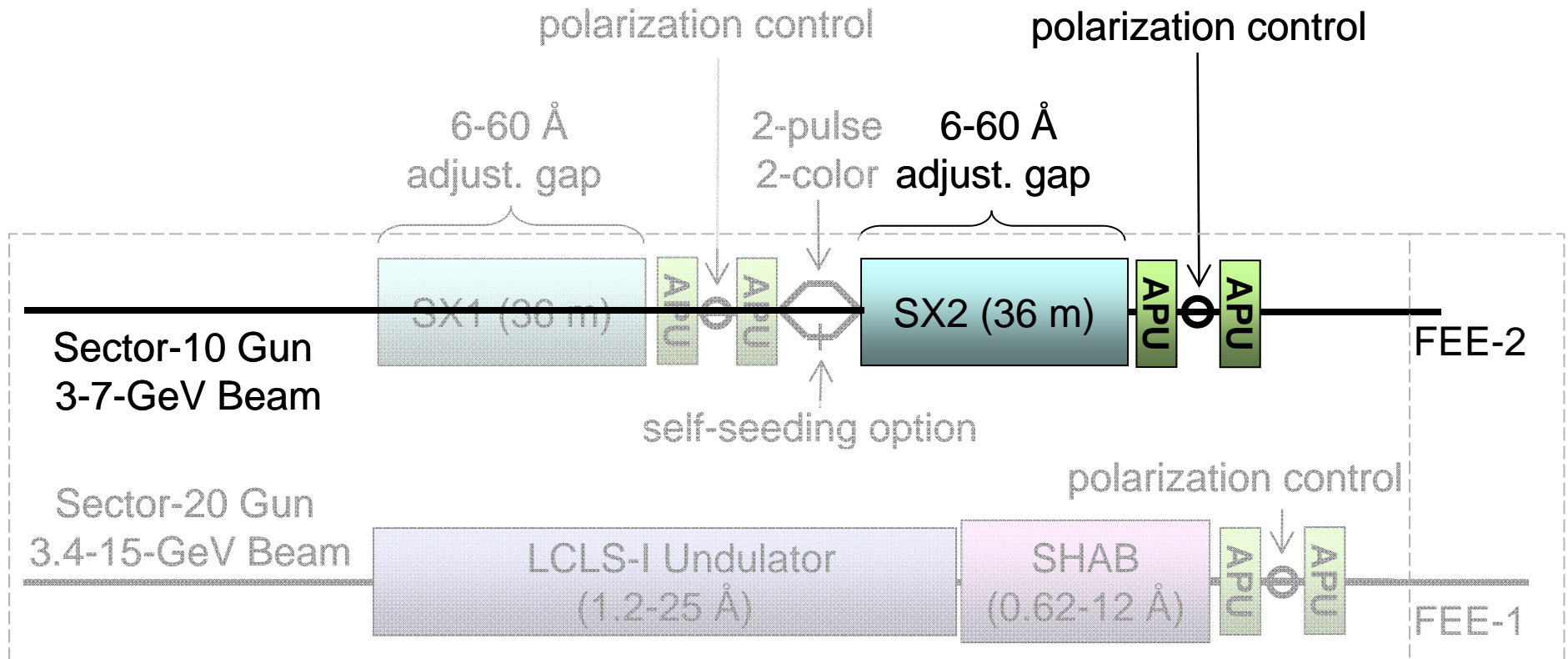
- 1. Hard X-ray SASE**
- 2. Soft X-ray SASE**
- 3. Soft X-ray Self Seeding**
- 4. Two-pulse, two-color soft x-rays (one e^- bunch)**
- 5. Two-pulse, two-color soft x-rays (two e^- bunches)**
- 6. Seeded soft x-ray FEL ('Echo')**
7. Self Seeding of hard x-rays (two e^- bunches)

1. *LCLS-II: Hard X-Ray SASE*



- 2nd harmonic after-burner in 2010 (0.62-12 Å, 1-2 GW)
- LCLS-II opens all 33 undulators gaps (0.62-12 Å, 5-20 GW)
- Or (?) replace all with variable gap (0.62-25 Å, 5-20 GW)

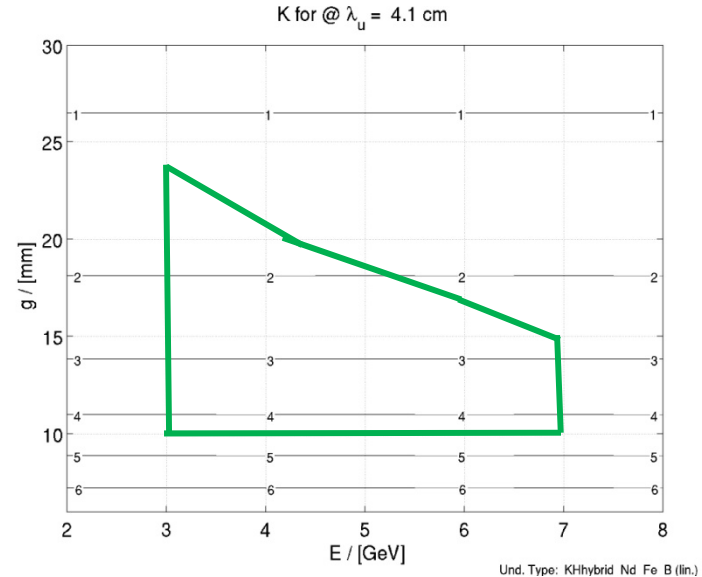
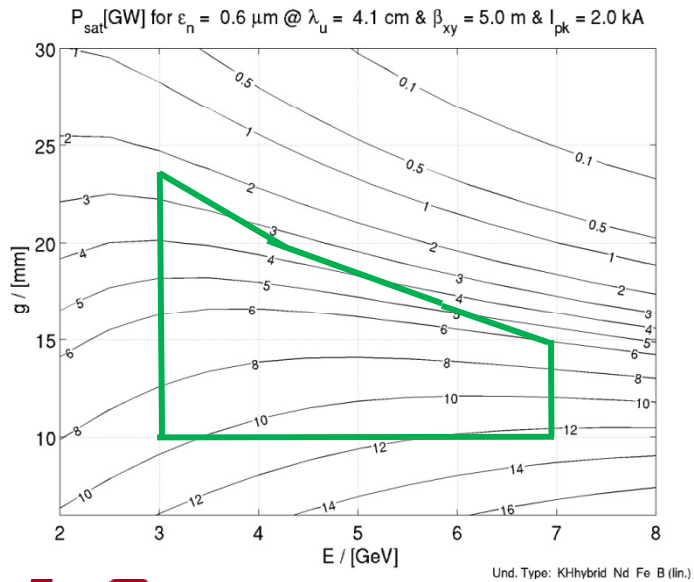
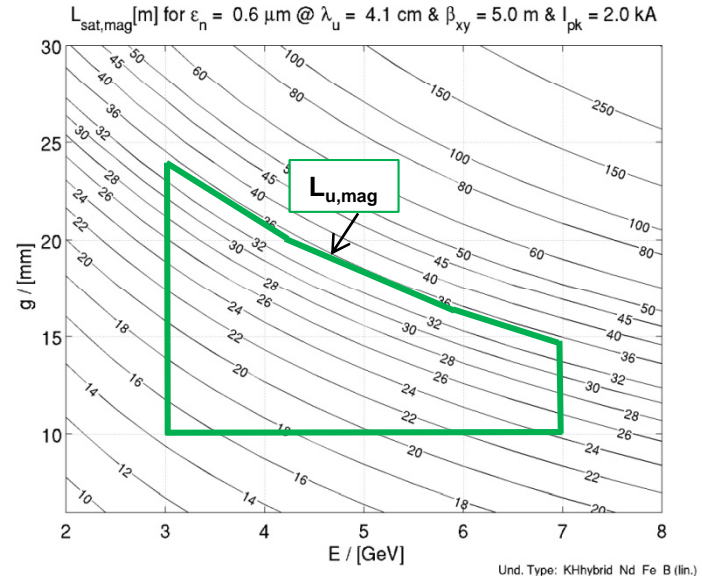
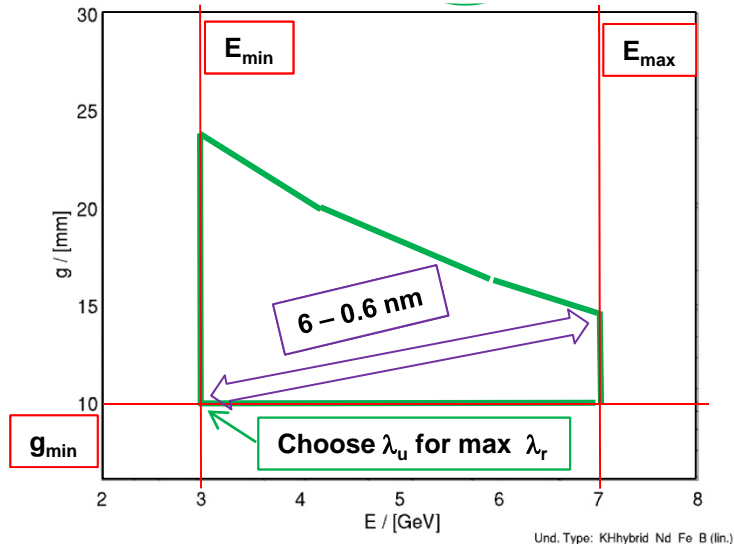
2. *LCLS-II: SX2 (or SX1) SASE*



- Simplest use of new soft x-ray line with SASE from SX2
- Full polarization control (fast at 80% or slow at ~100%)

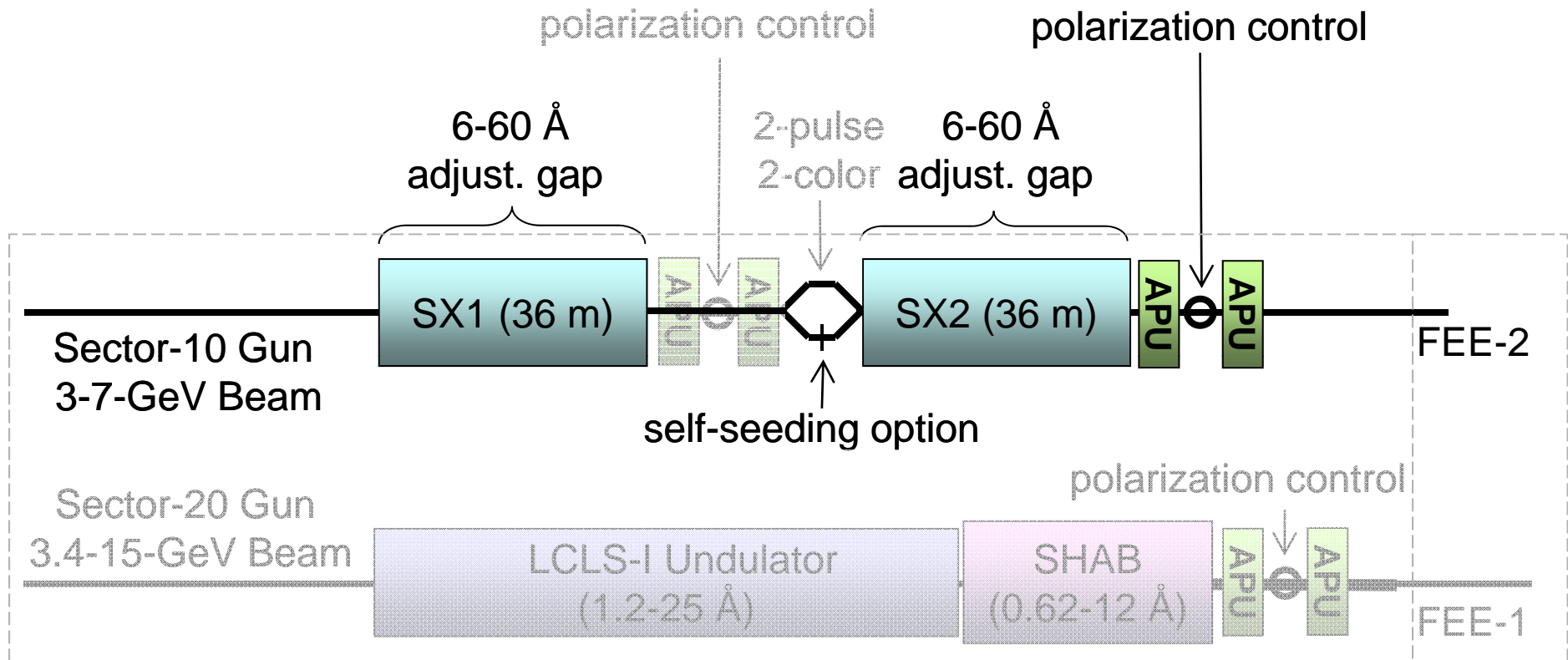
LCLS-II: SX1/SX2 Undular Design

max λ_r : 6 nm



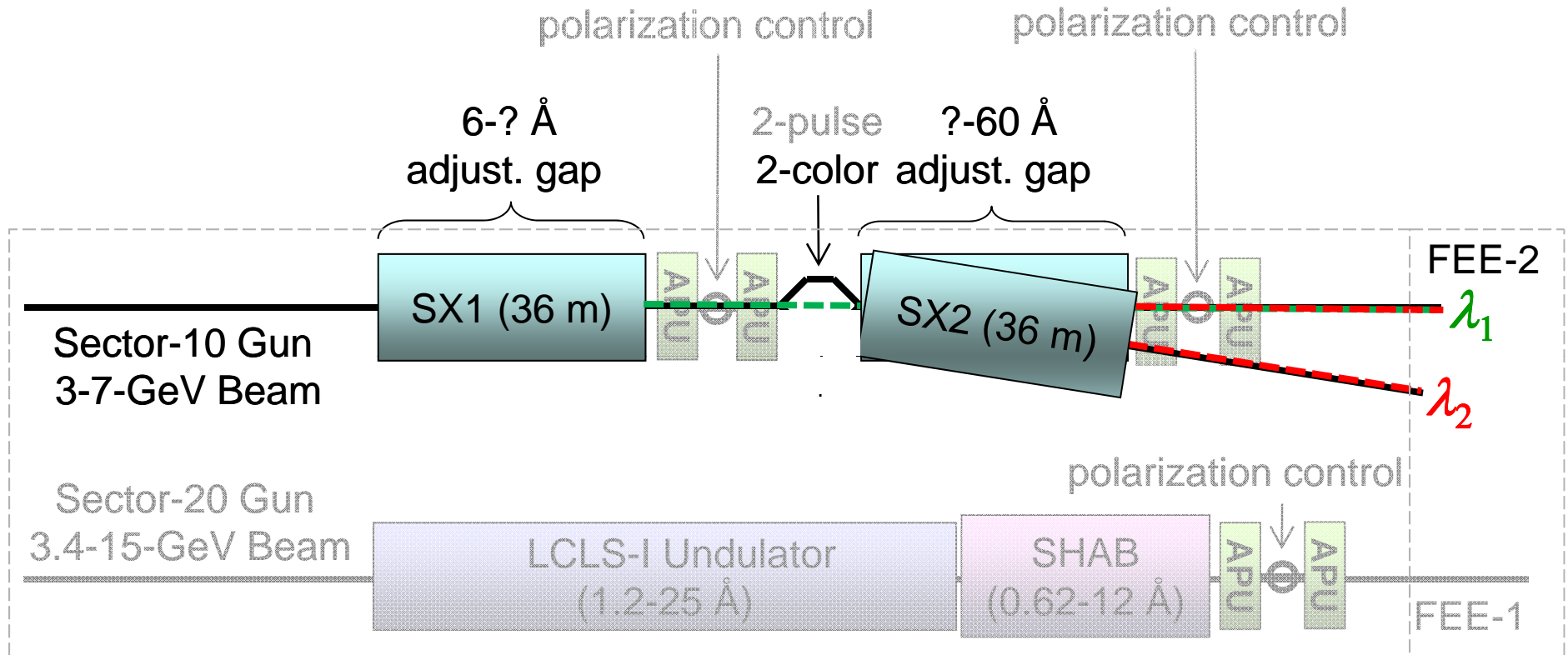
$I_{pk} = 2000$ A, $\gamma\epsilon_{xy} = 0.6$ μ m
 $\langle\beta\rangle = 5$ m, $\sigma_y = 2.8$

3. *LCLS-II: Soft X-Ray Self-Seeding*



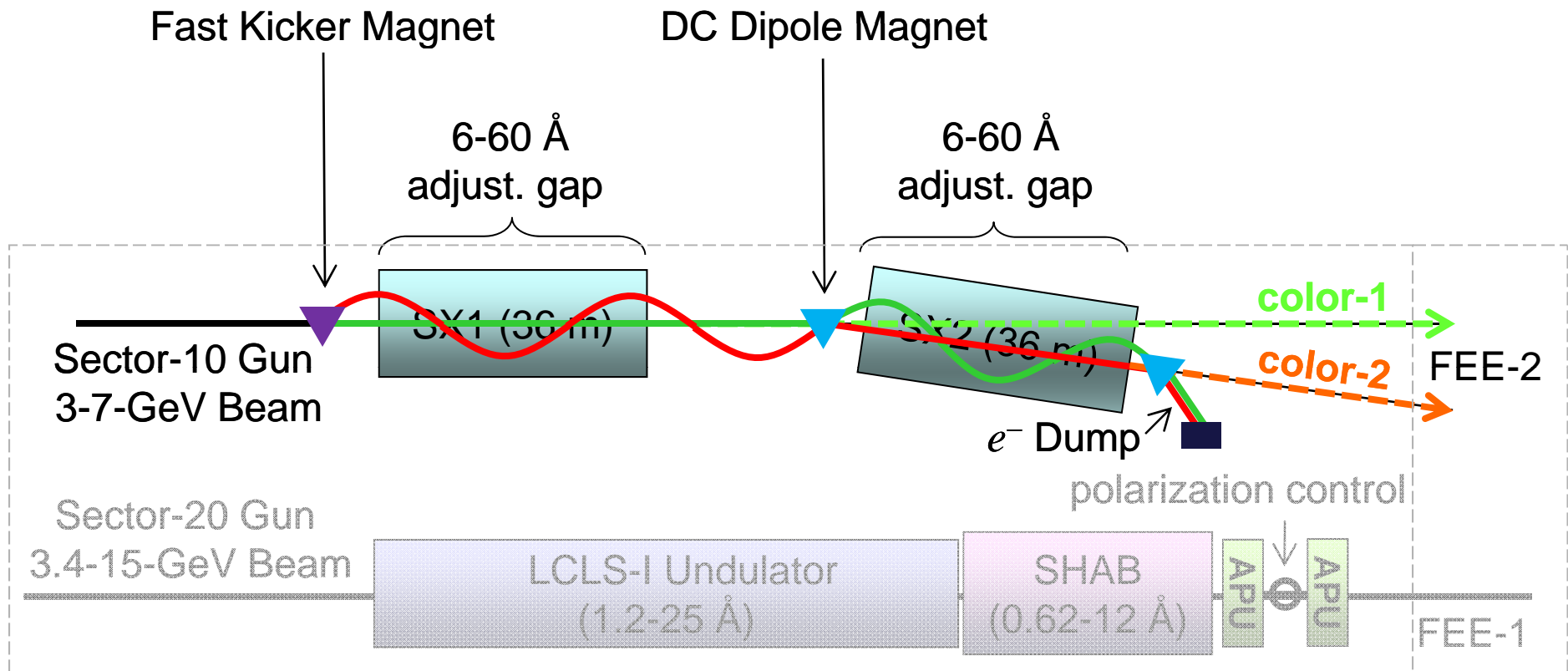
- SX1 pulse passes monochromator and seeds SX2 pulse
- Narrow bandwidth SXR pulse BW to $<10^{-4}$ FWHM (6-60 Å)
- Can also use chirped bunch to generate short pulse (<50 fs)

4. LCLS-II: SX1&2 SASE, One-Bunch, Two-Color



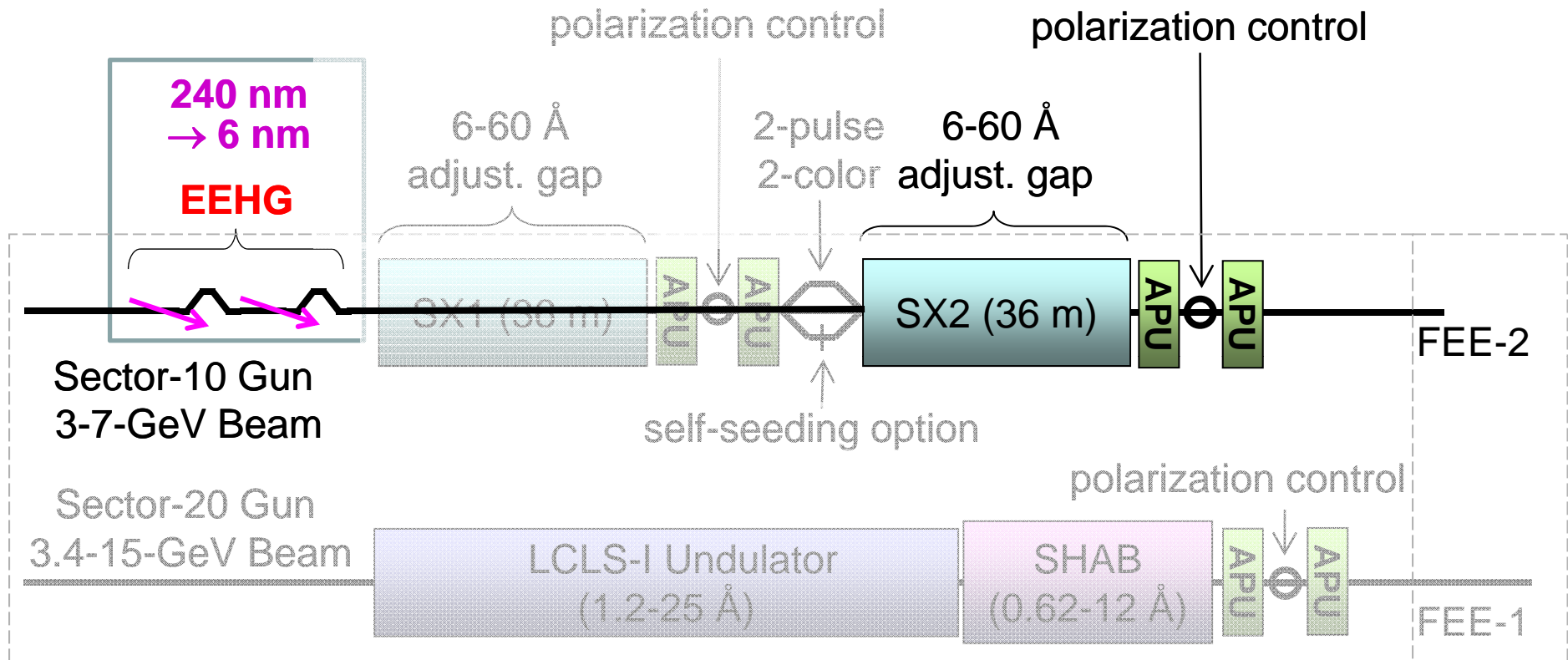
- One e^- bunch produces 2 SXR pulses (0-15 ps separation) for pump probe
- Deliver both pulses to one experiment or split them to two
- SX2 pulse color (λ_2) must be longer wavelength than SX1 (λ_1)

5. LCLS-II: SX1&2 SASE, Two-Bunch, Two-Color



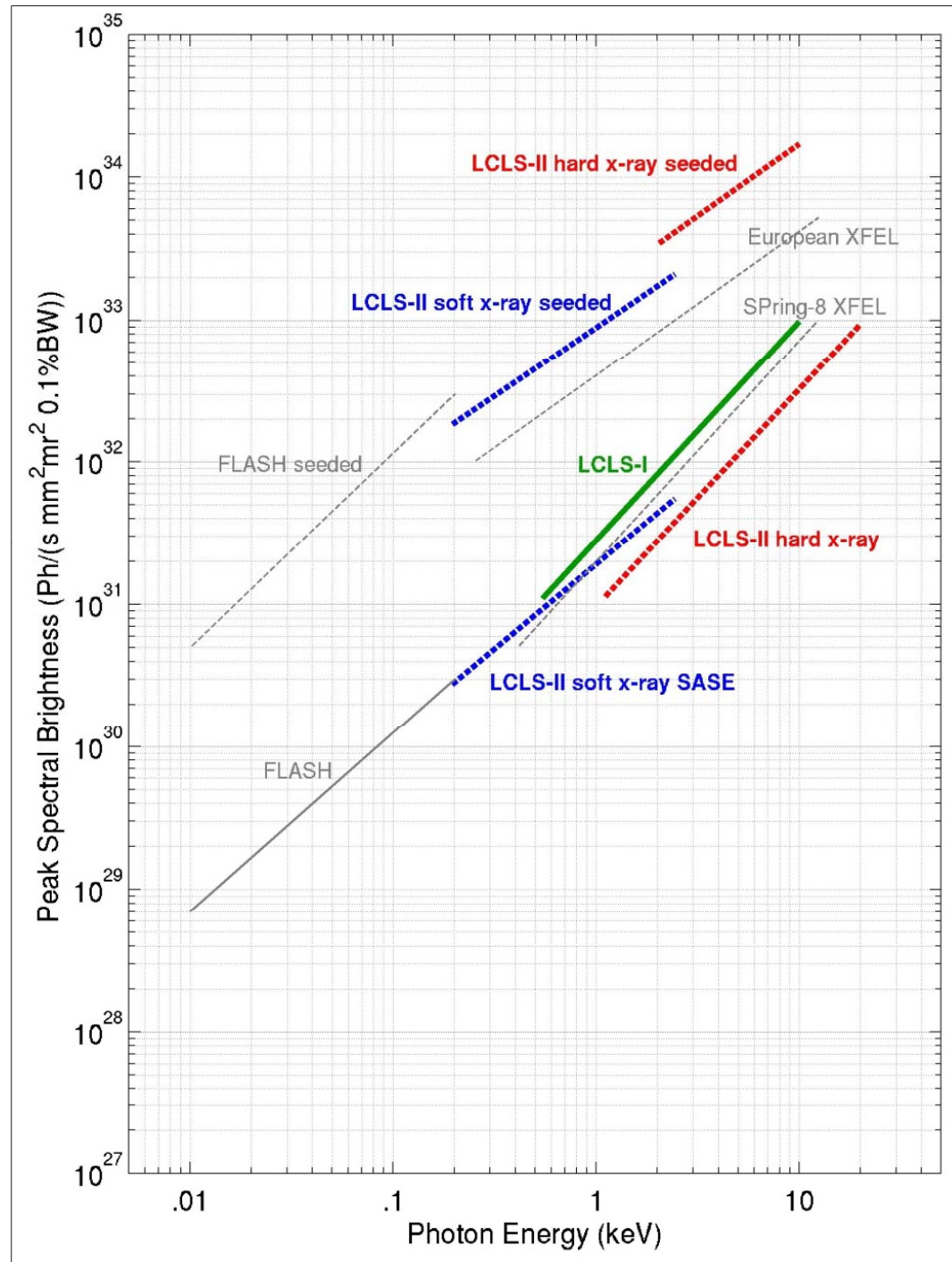
- Two e^- bunches 10-100 ns apart (no pump probe here)
- One fast kicker & one DC – each bunch lases in just one FEL
- Allows 2 SXR experiments simultaneously (*user doubler*)
- Two colors can be any value (6-60 Å)

6. LCLS-II: Echo Seeding of SX1 or SX2

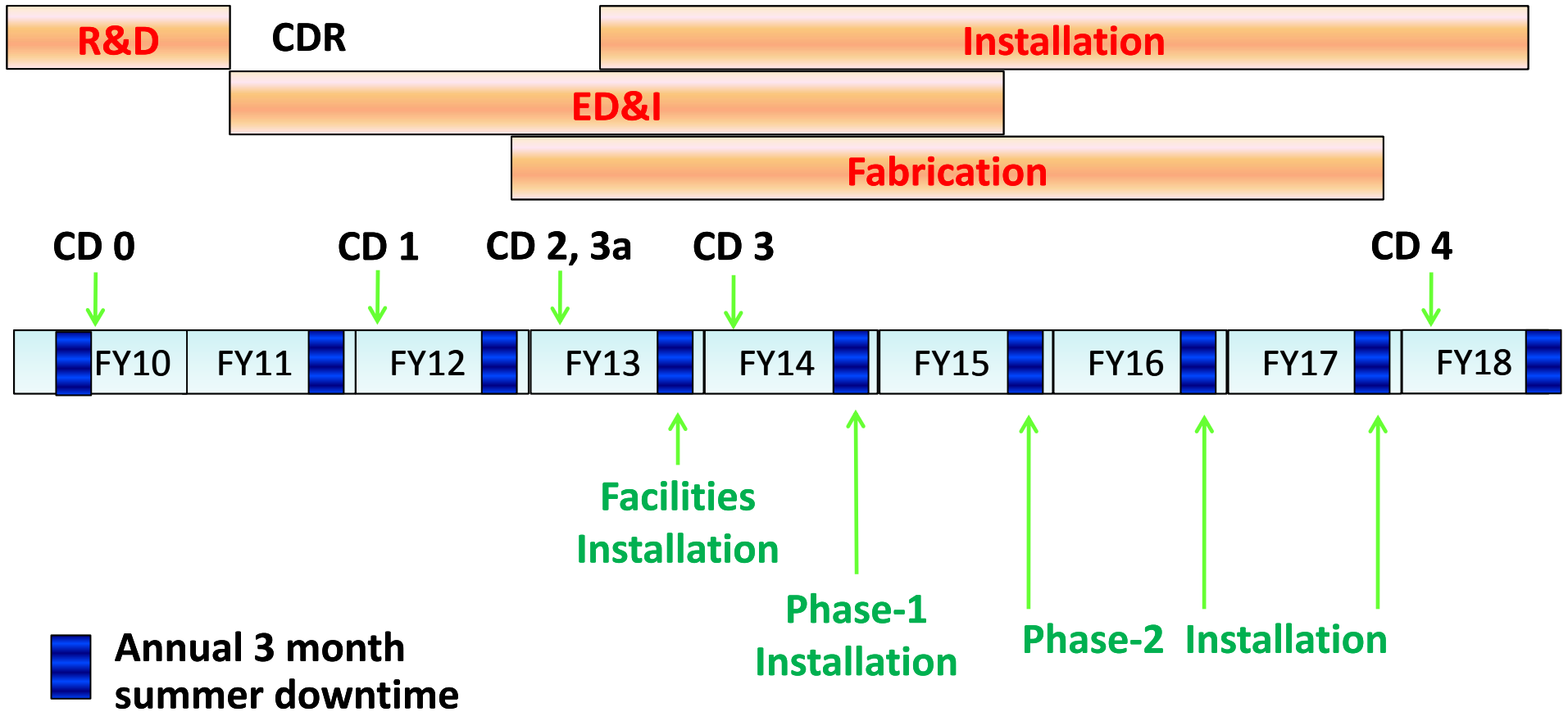


- External seeding (30-60 Å) using Echo-Enhanced Harmonic Generation (EEHG*)
- Allows narrow BW and longitudinal coherence

Peak Brightness



LCLS-II Timeline, Compatible with Operations



LCLS-II Summary

Soft X-Rays:

- Two-pulse, two-color, variable delay (6-60 Å) using one e^- bunch or two
- Self-seeding option for narrow bandwidth ($\sim 10^{-4}$ at 6-60 Å)
- Full polarization control in both SASE and self-seeded modes (fast & slow)
- Single femtosecond near-transform limited spike in low-charge mode
- 3-7 GeV bypass line allows simultaneous soft and hard x-ray operations in two separate beamlines with completely independent parameters

Hard X-Rays:

- Shorter wavelength hard x-rays (0.62 Å) by modifying all undulators
- 2-10 femtosecond pulses possible in low-charge mode
- Full polarization control at any fundamental wavelength
- Self-seeding option with two electron bunches and a short chicane (4 m)
- And... 22-30 GeV still possible by using both 1-km linacs (3rd km still open)

End of Presentation