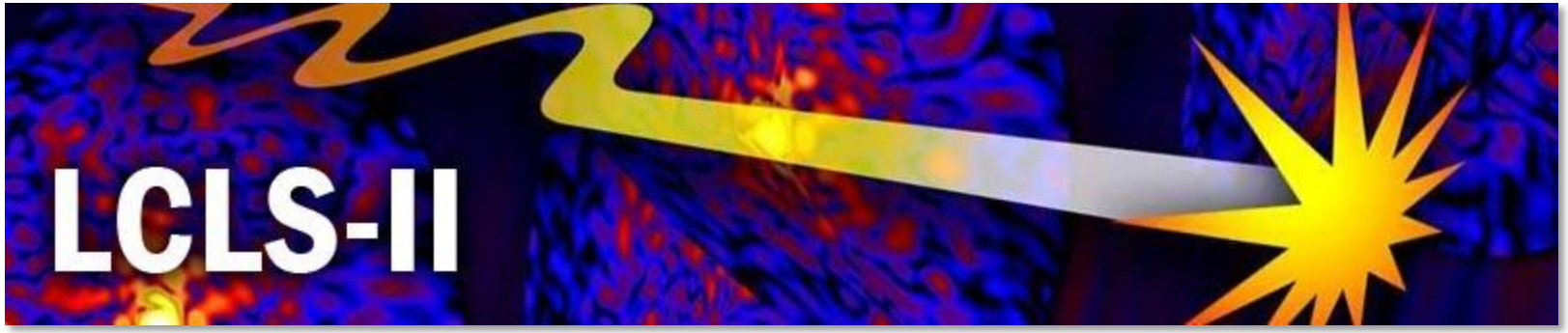
LCLS
LINAC COHERENT LIGHT SOURCE

ACCELERATOR DIRECTORATE
Office of Science
U.S Dept. of Energy

FEL

LCLS-II: An upgrade for the LINAC Coherent Light Source



J. Wu *for* ***LCLS team***

August 24, 2010

32nd International Free Electron Laser Conference

Hilton Malmo City, Sweden, August 23-27, 2010

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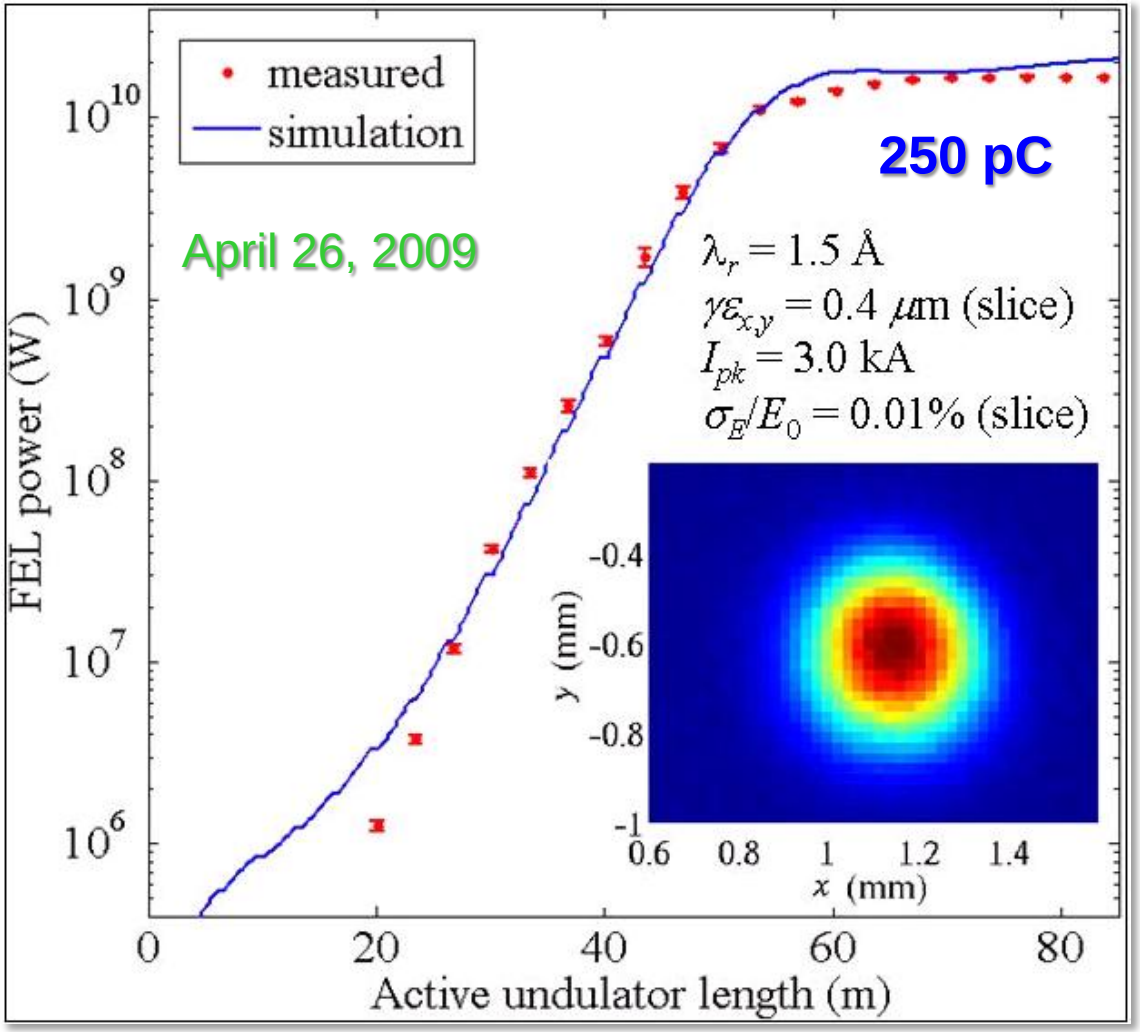
LELAND STANFORD JUNIOR UNIVERSITY
DIE LUFT DER FREIHEIT WEHT
1891

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

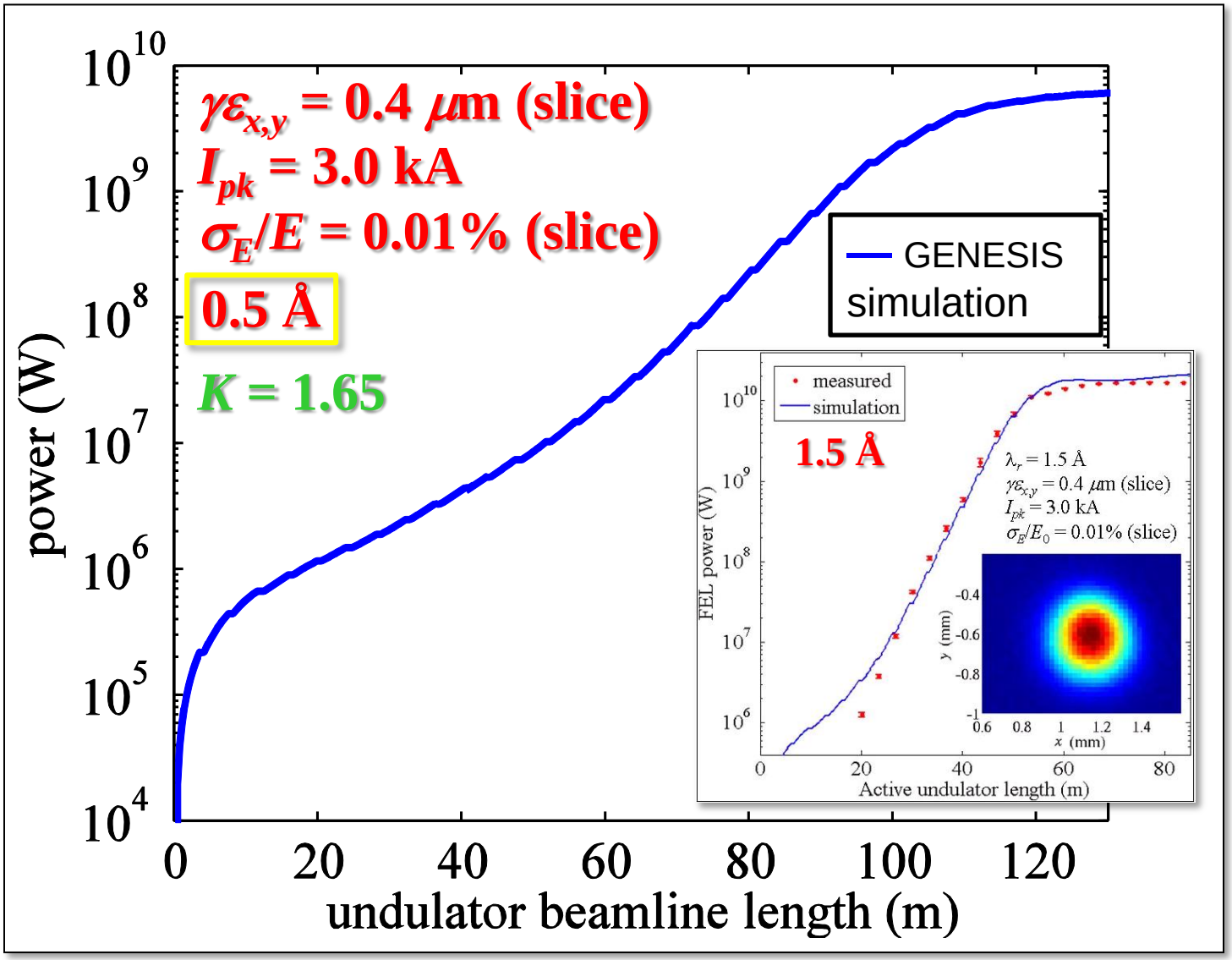
The success of the LINAC Coherent Light Source (*LCLS**) motivates an extension of the capacity, capabilities, and quality of this revolutionary new light source.



*LCLS, P. Emma *et al.*, Nature Photonics, 2010, (PUBLISHED ONLINE: 1 AUGUST 2010 | DOI: 10.1038/NPHOTON.2010.176)

LCLS beam should support 25-keV (0.5 Å) FEL at 14 GeV

undulator gap has been increased here



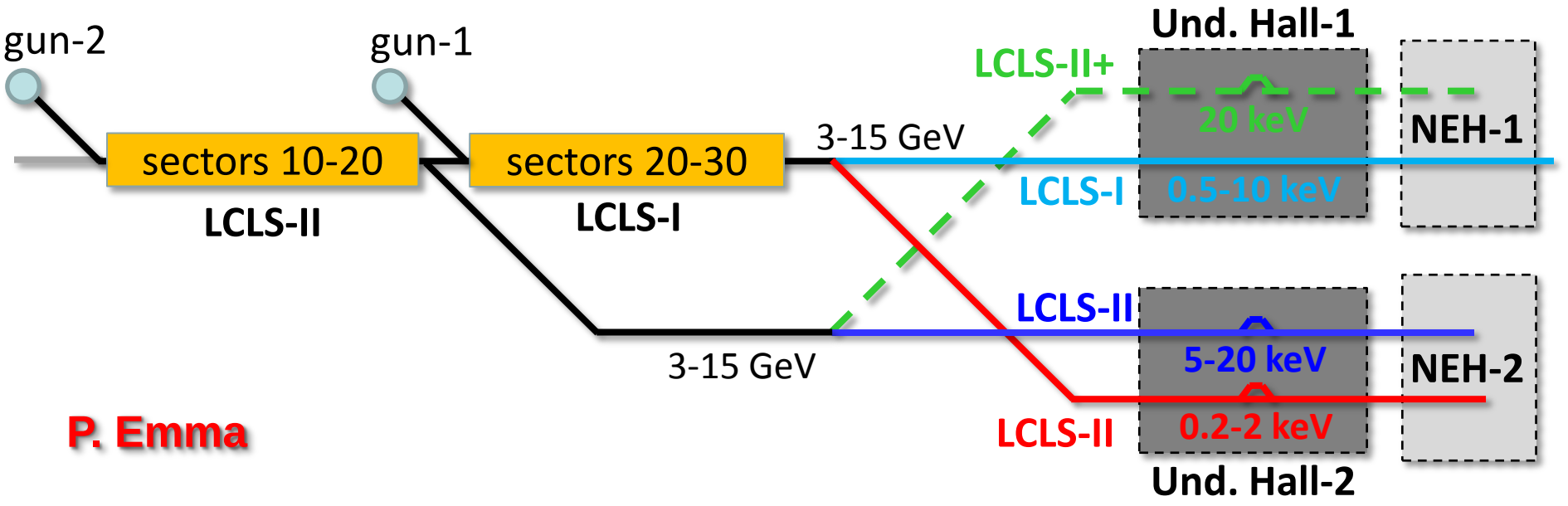
Same beam quality and energy as now

LCLS-II Requirements

- Build new soft x-ray line from 250 to 1800 eV
- Extend hard x-rays out to ~20 keV
- Include seeding options for narrow BW (if $)
- Incorporate 2-pulse, 2-color schemes (if $)
- Provide polarization control
- Use more of 3-km **SLAC** linac to provide separate sources for independent FELs
- Explore multi-bunch operations (NOW TESTED)
- **Find ways to increase capacity** (user access)!

Schematic Layout of *LCLS* in the Future

- Possible new undulator tunnel (hall)
- Budget still being developed – within range of 300-400 M$
- *LCLS-II* incorporates as many of these capabilities as budget allows



All electron beamlines support up to 15 GeV at 120 Hz (or 7 GeV at 360 Hz) and two-bunch operation is available from either gun

3-4 FELs and 2 Electron Sources (& more)

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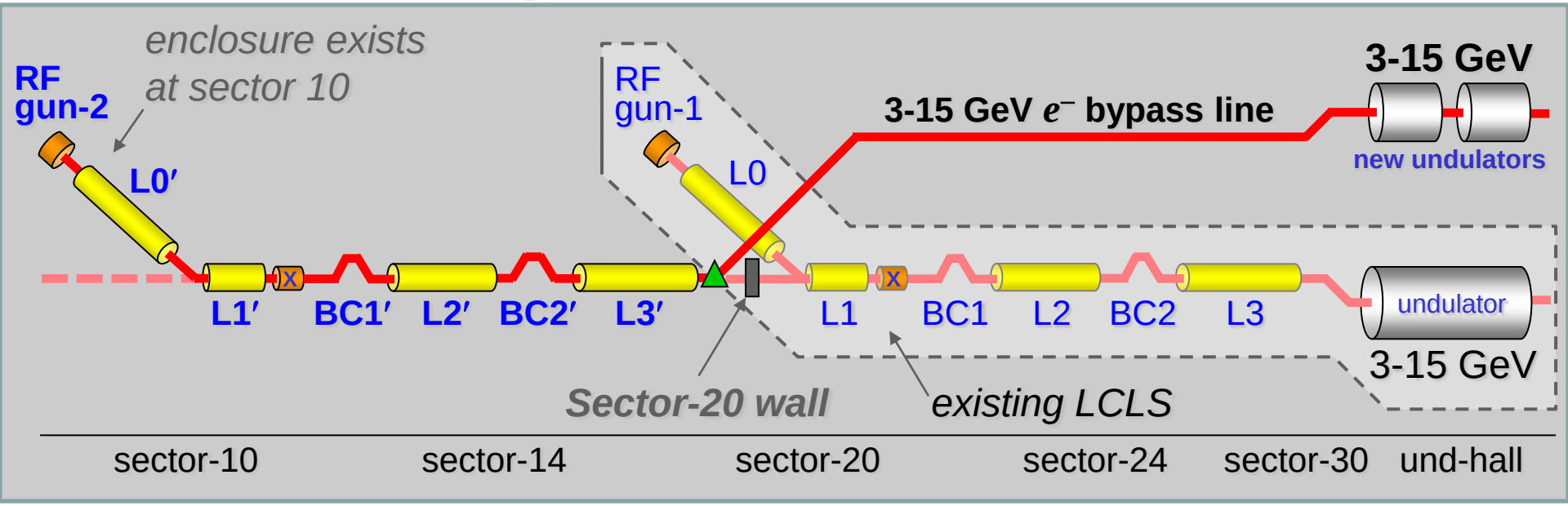
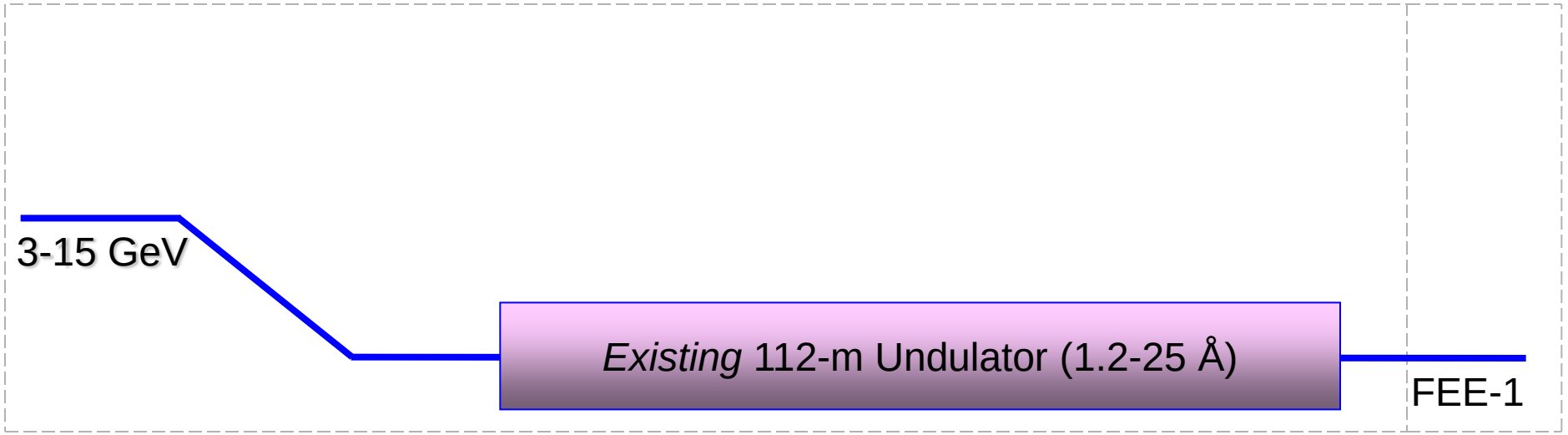
LCLS-II: New Injector & Accelerator



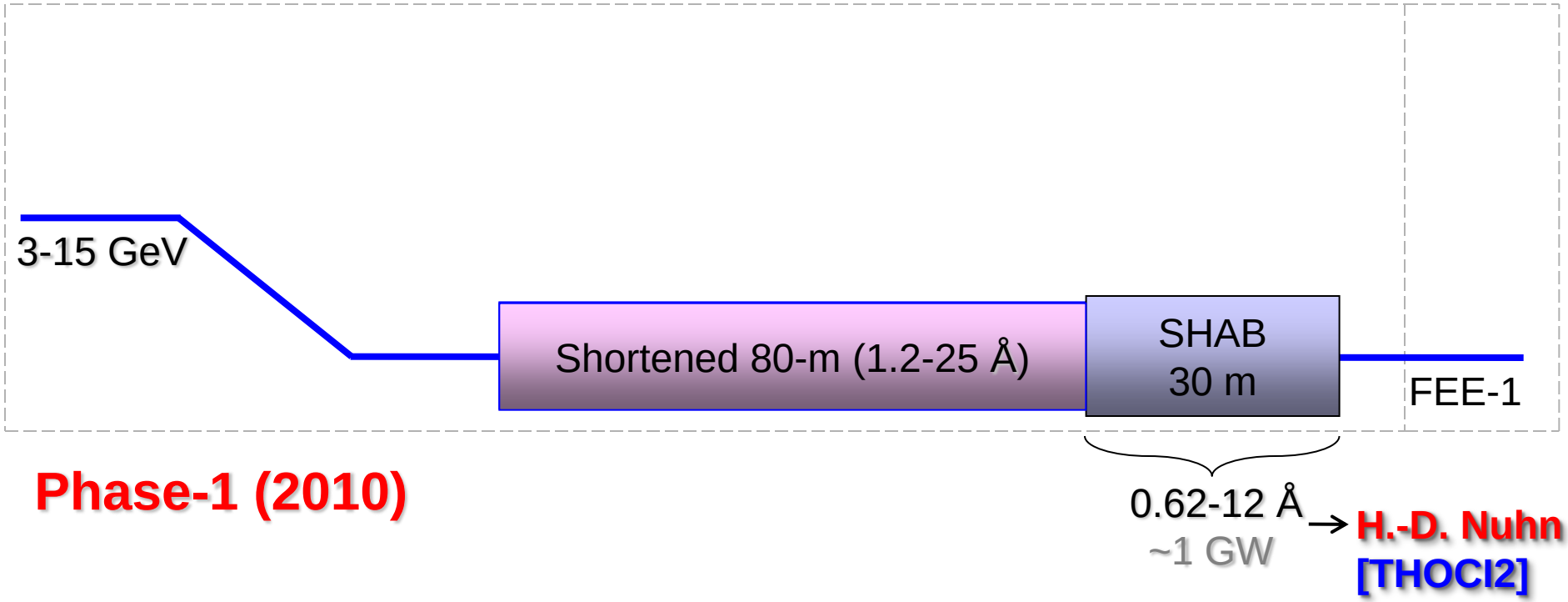
- Use 2nd km of SLAC linac (sector-10 to 20) – greater flexibility
- 3-15 GeV energy at 120-Hz beam rate; or 3-7 GeV energy (no SLED) allowing 360-Hz beam rate
- 2nd injector, linac, & bypass line allows 2+ independent FELs serving 2+ experiments simultaneously with flexible parameters
- Combining beams allows x-ray pump/probe with decoupled wavelengths, pulse width, energy, and timing; and even THz x-ray pump/probe
- Preserves possibility of up to 30 GeV (and still 1 more km left!)

Phased Enhancement Options for *LCLS-II* FELs



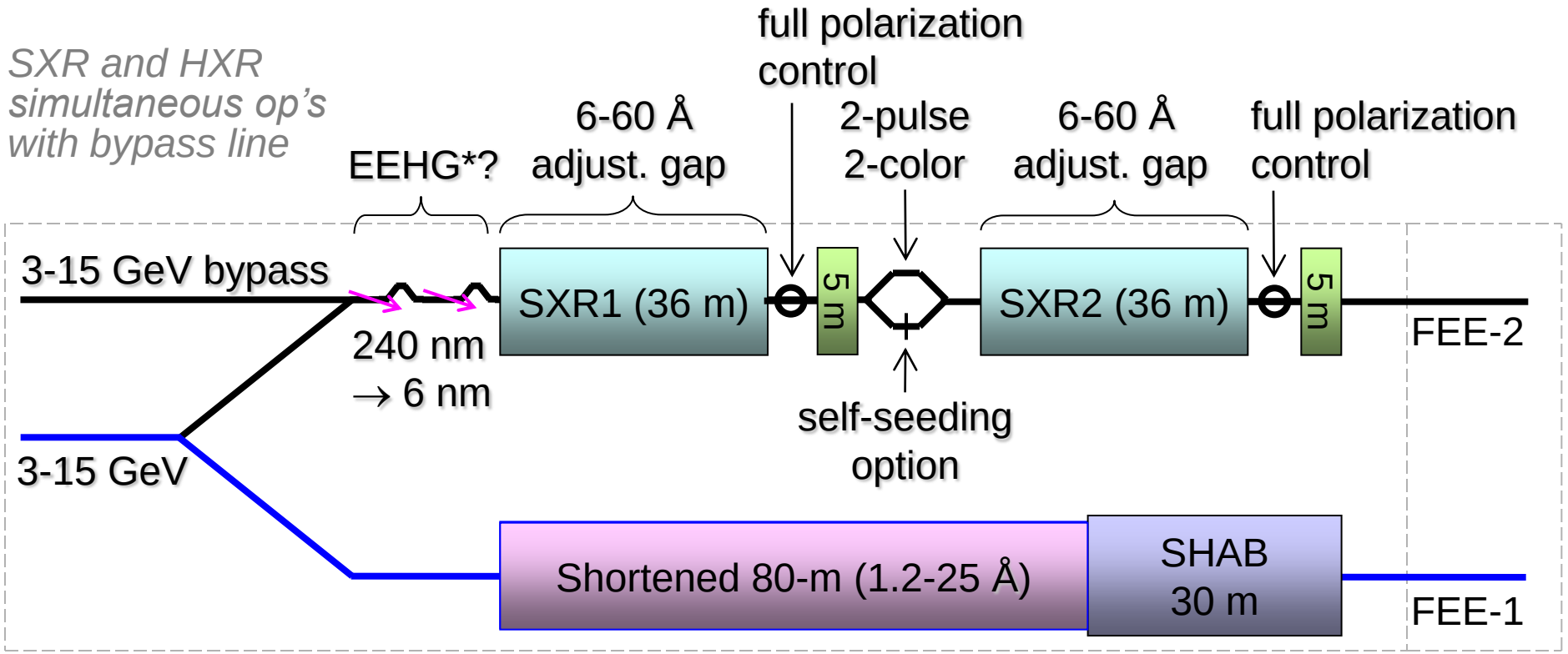
Existing

Phased Enhancement Options for *LCLS-II* FELs



Phased Enhancement Options for *LCLS-II* FELs

SXR and HXR simultaneous op's with bypass line

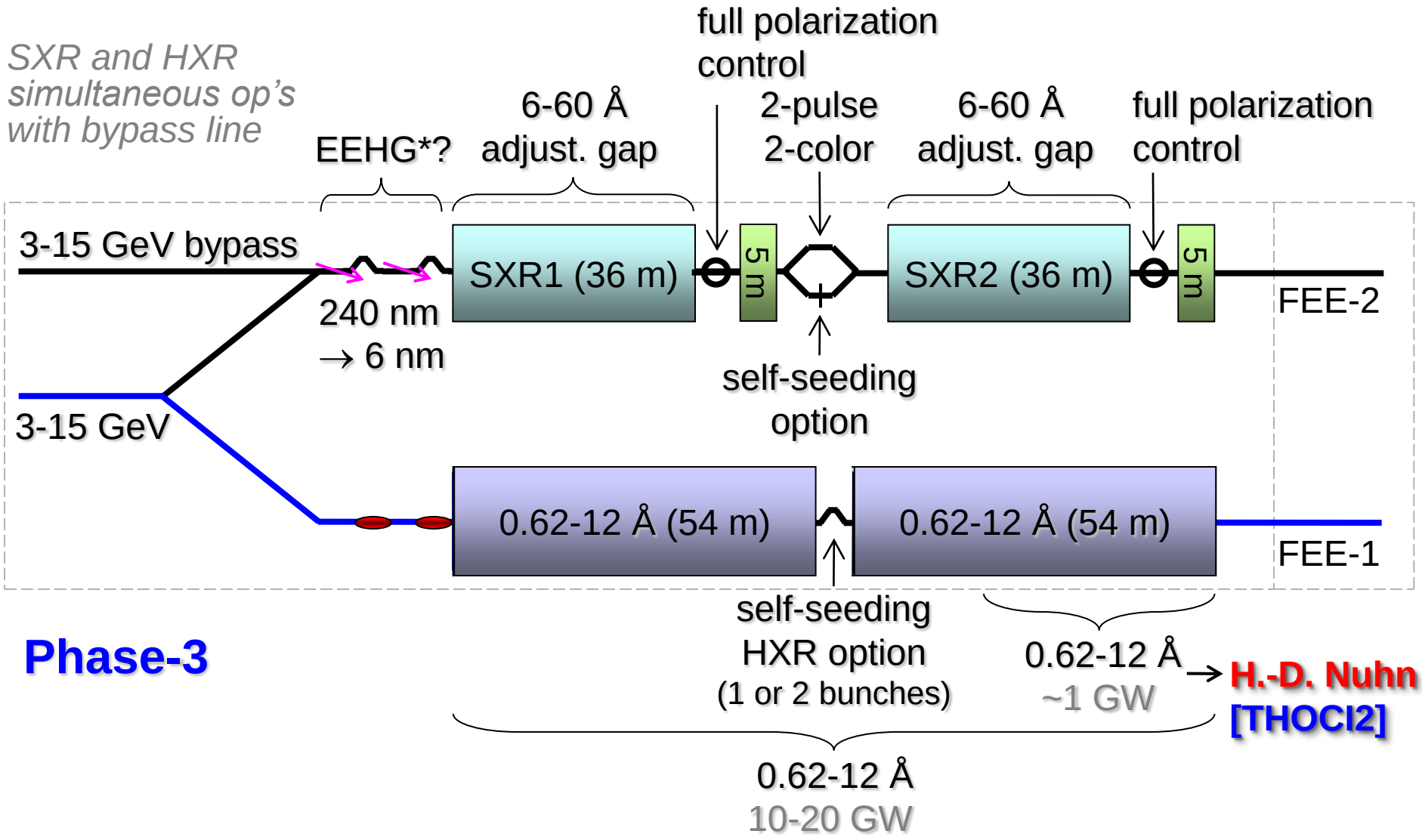


Phase-2

→ **H.-D. Nuhn [THOCI2]**

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

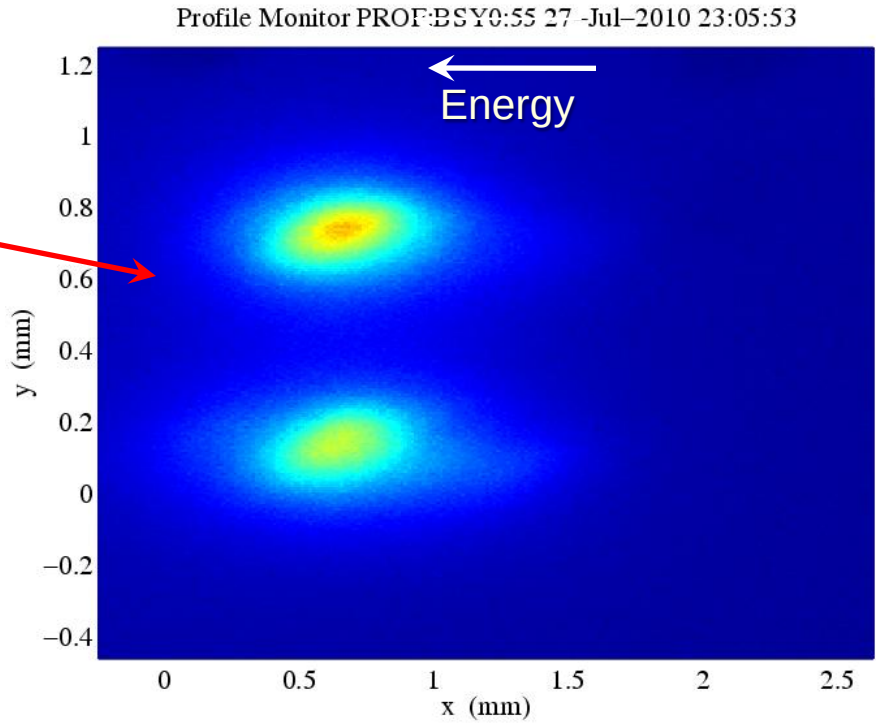
Phased Enhancement Options for *LCLS-II* FELs

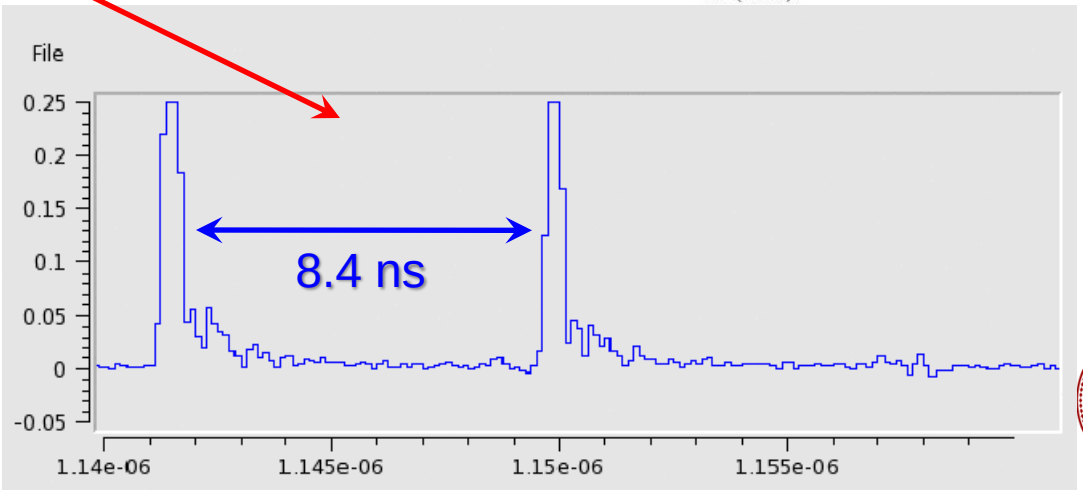


* G. Stupakov, Phys. Rev. Lett. **102**, 074801 (2009)

Two bunch demonstrated at *LCLS-I*

- Two electron bunches observed on OTR screen with TCAV3 separating them
- Two FEL beams observed on SXR Antenna





F.-J. Decker [WEPB33]

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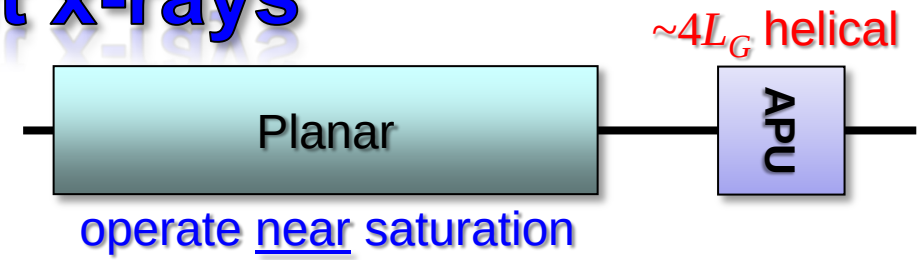
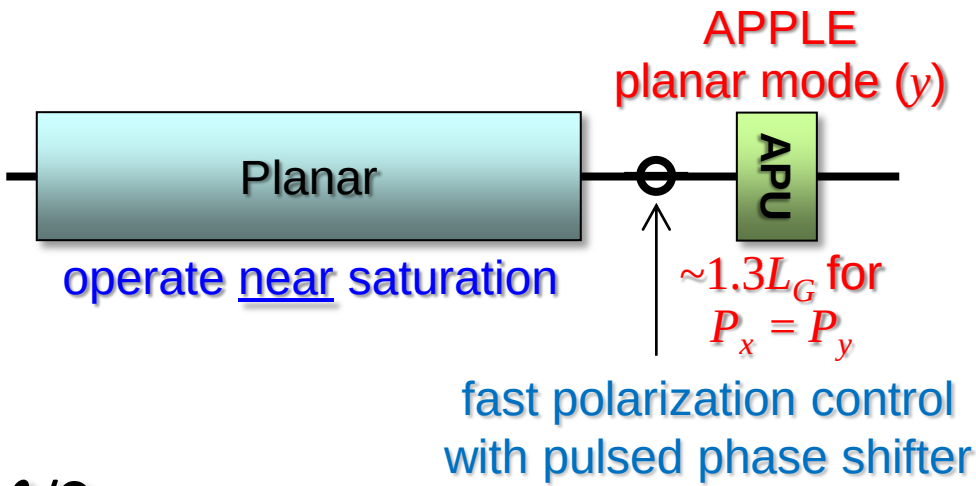
"Circular" Polarization Control Options

Soft x-rays

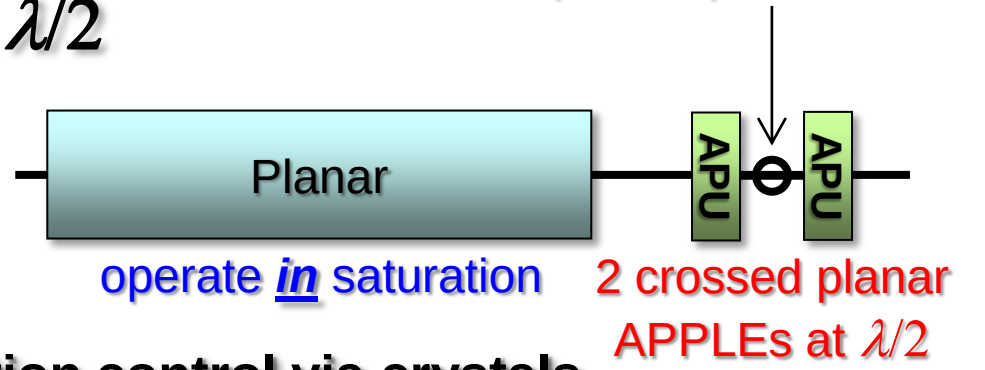
- **Planar + Helical**
  - Stable
  - >90% polarization
  - Slow switching



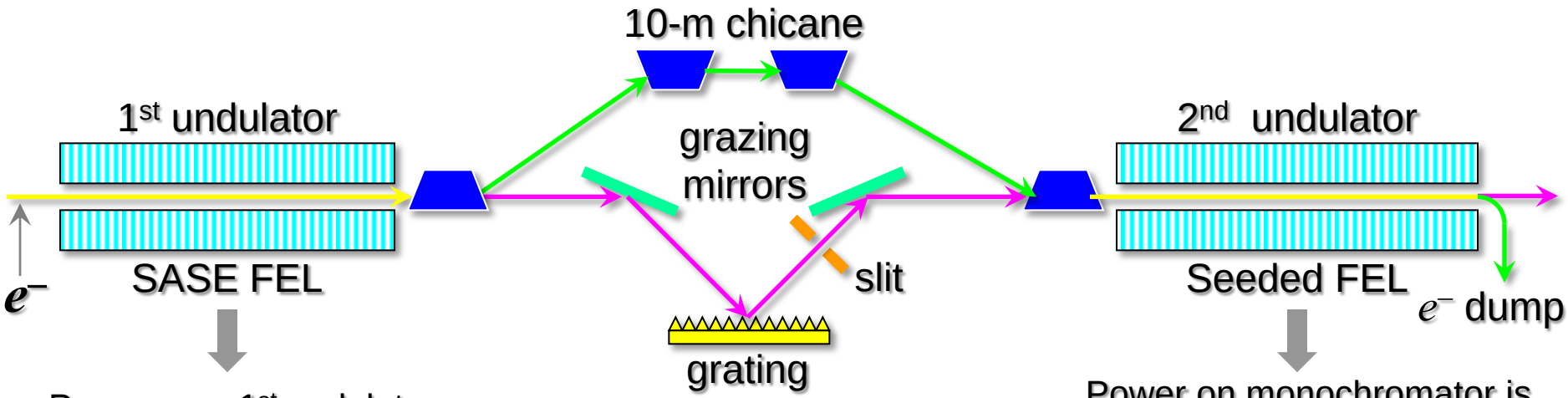
- **Planar + Crossed Planar**
  - May have fluctuations
  - ~80% polarization
  - Fast switching



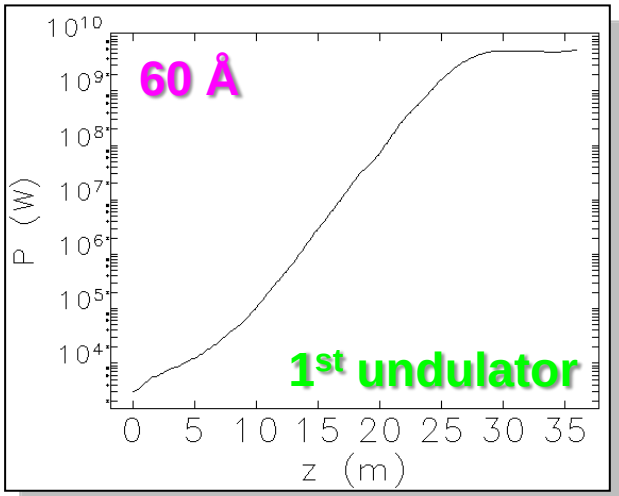
- **Planar + Crossed Pair at $\lambda/2$**
  - Stable
  - ~90%
  - Fast switching
  - ~1% of fundamental power



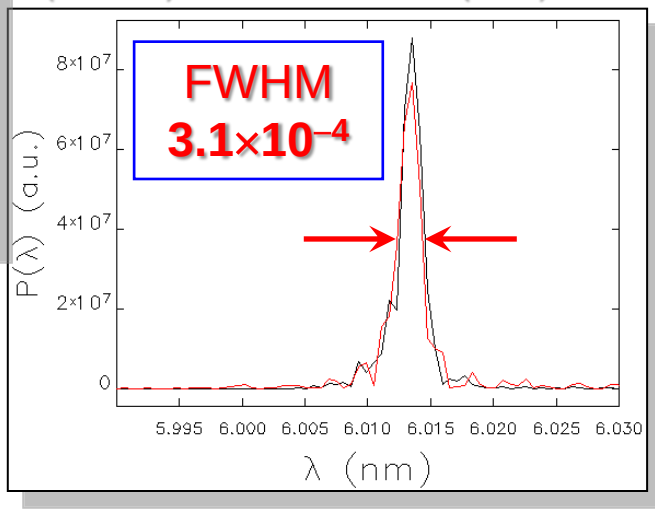
Self-Seeded SXR (6-60 Å) FEL in *LCLS-II*



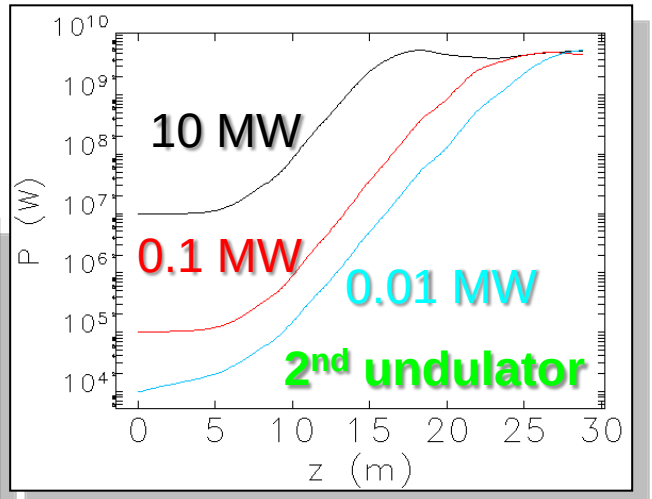
Power over 1st undulator



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

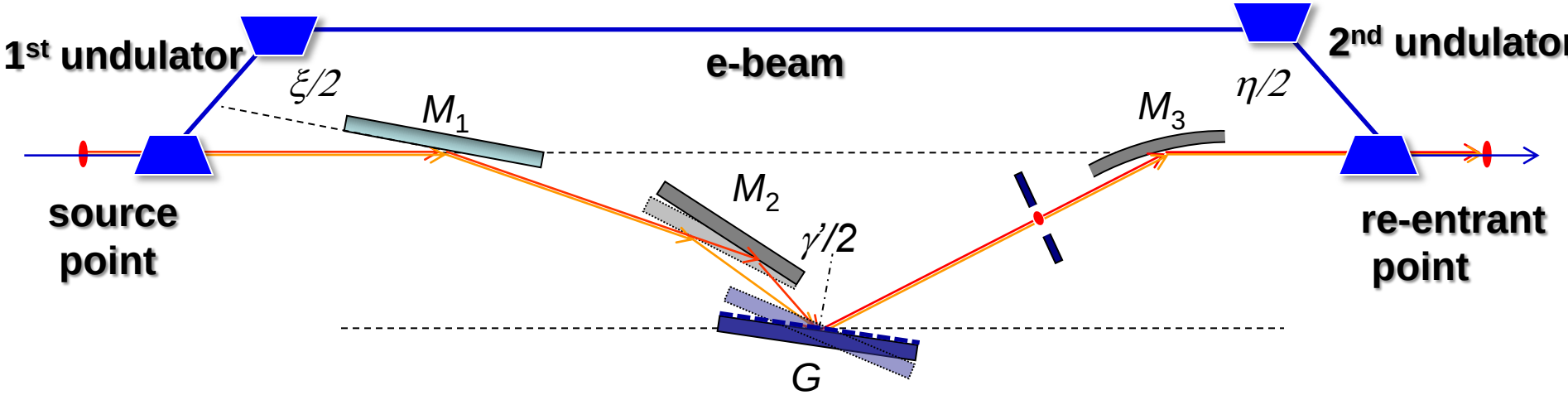


Power on monochromator is amplified



J. Wu *et al.* [TUPB08]

Optics Self-Seeded SXR FEL in *LCLS-II*



- Electron bypass chicane and the photon optics can (may have to) be in two orthogonal planes, one in *x*– and the other in *y*–plane
- R_{56} of the chicane is about 3 mm; *h* (excursion) ~ 10 cm.
- (rotational) Planar variable-line-spacing grating G;
- Constant focal-point mode → fixed slit location, but optical delay varies when tuning energy (~5 ps +/- 10%)

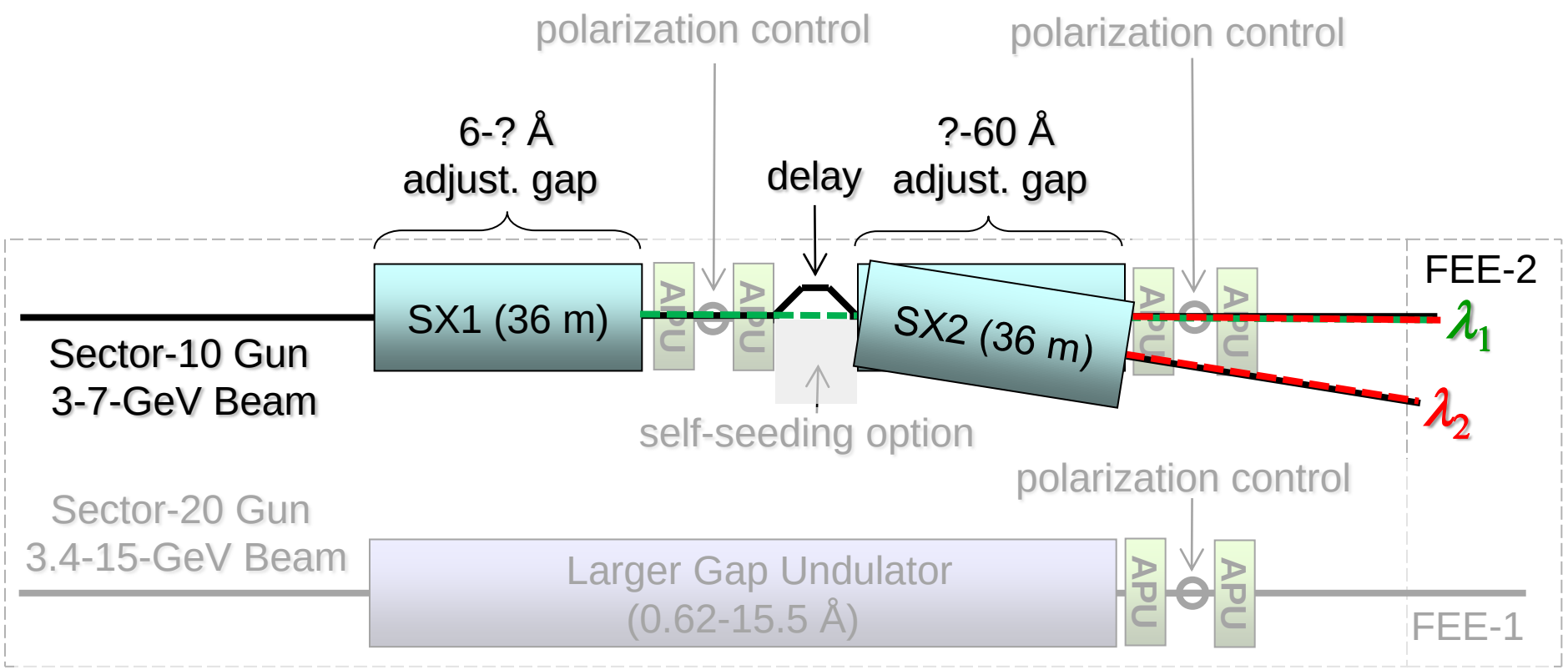
Y. Feng *et al.* [TUPB10]

The next 4 slides will graphically outline 4 future operating modes…

(thanks to H.-D. Nuhn)

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 (single and two e^- bunches)

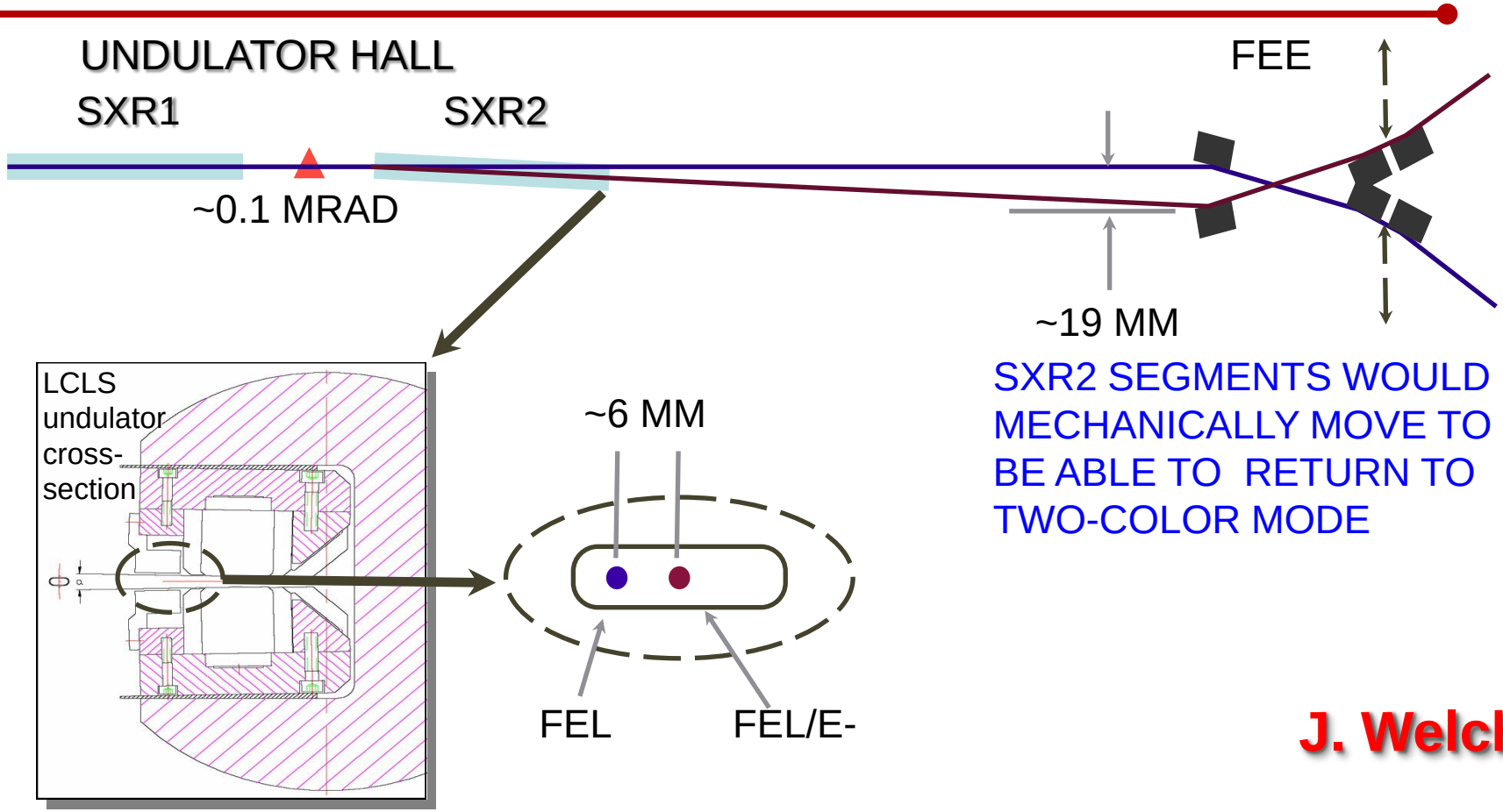
4. *LCLS:* SX1 & 2 SASE, *One*-Bunch, Two-Color



- One e^- bunch produces 2 SXR pulses (0-10 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)

Angled SX2 suggested by J. Hastings and P. Heimann

Beam Doubler Layout



SXR2 SEGMENTS WOULD MECHANICALLY MOVE TO BE ABLE TO RETURN TO TWO-COLOR MODE

J. Welch

- INSERTABLE MIRRORS PAIRS FOR 0 OR 60 MRAD DEFLECTION
- FOUR POSSIBLE BEAMLINES, TWO ACTIVE AT ANY TIME

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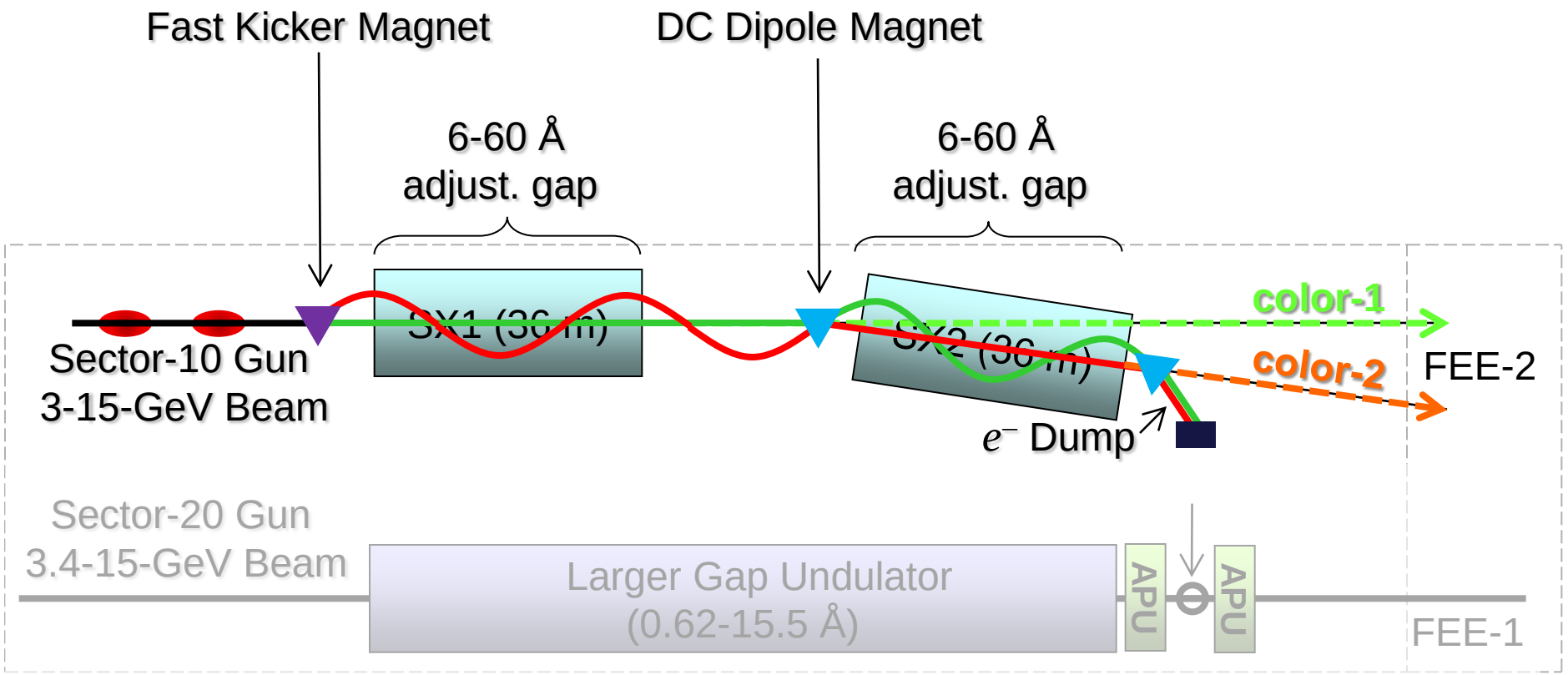
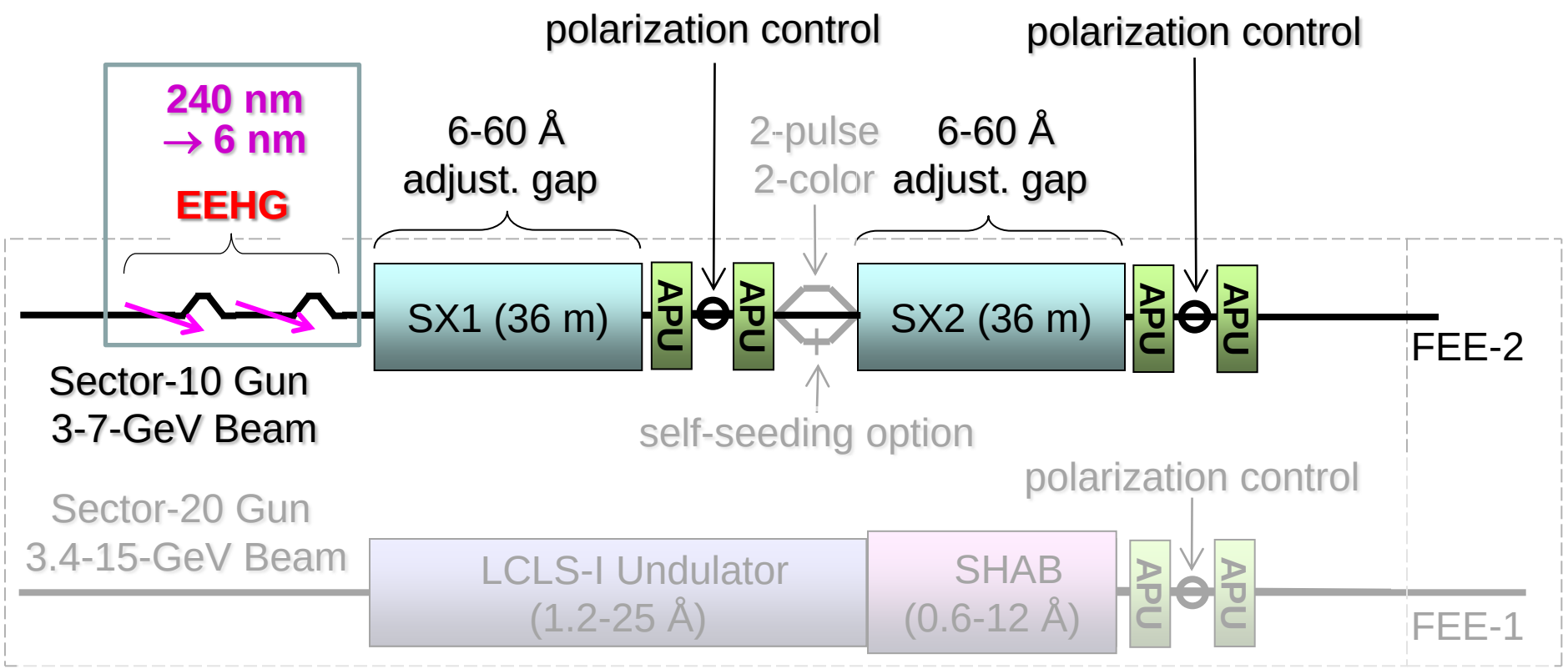
5. *LCLS:* SX1 & 2 SASE, *Two*-Bunch, Two-Color



- 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)

Suggested by J. Frisch and independently by R. Brinkmann *et al.*

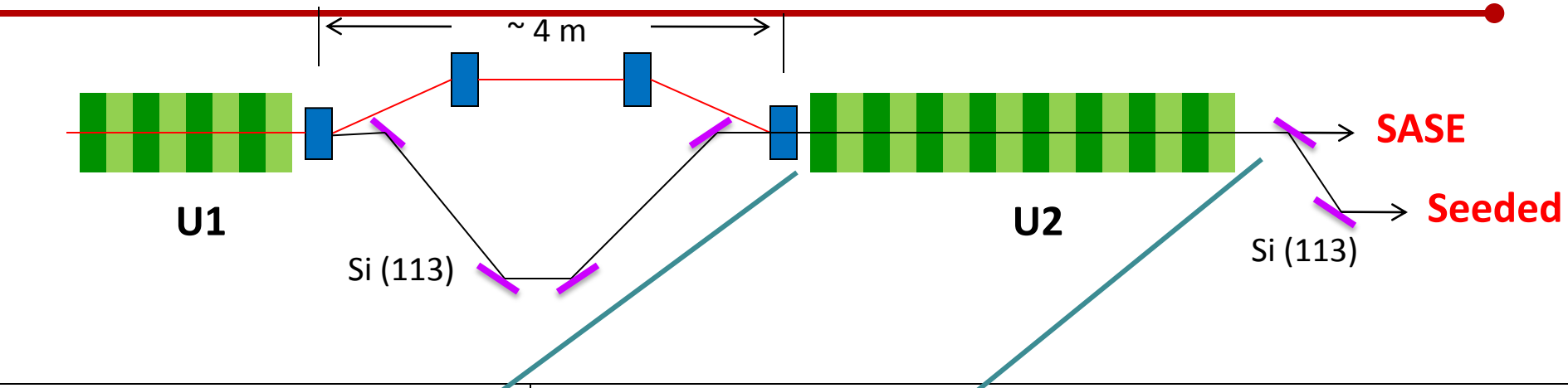
6. *LCLS:* Echo Seeding of SX1 or SX2

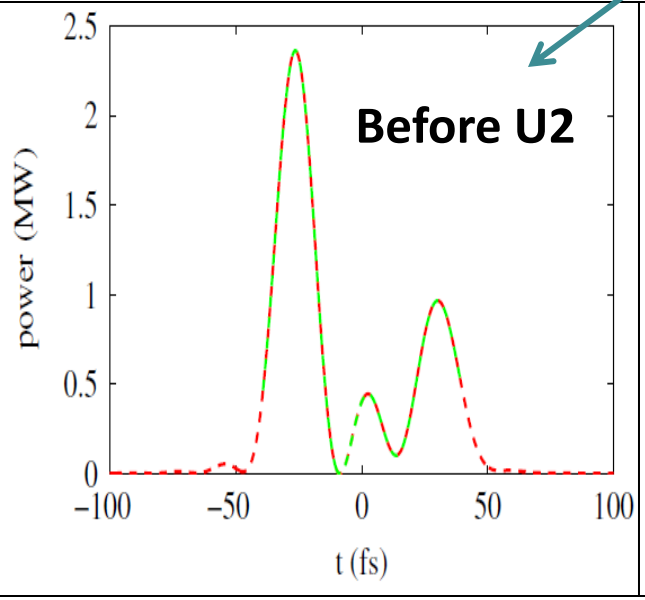


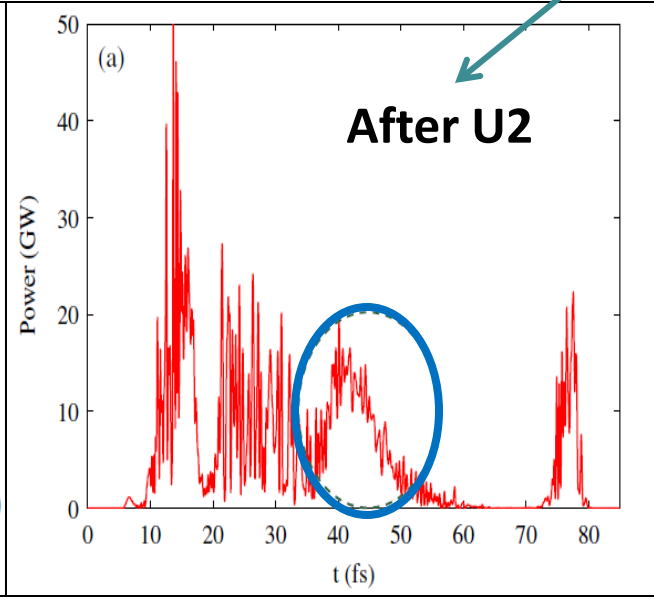
- External seeding (~30-60 Å) using Echo-Enhanced Harmonic Generation (EEHG*)
- Allows narrow bandwidth and longitudinal coherence
- Under study now at NLCTA/SLAC (**S. Weathersby [WEOA3]**)

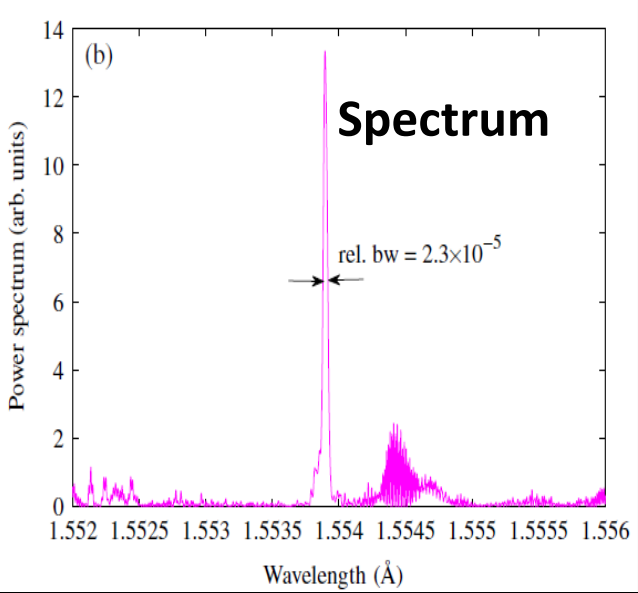
* D. Xiang, G. Stupakov, [**TUPB13**]

7. *LCLS:* Two-bunch HXR Self-seeding









Y. Ding, Z. Huang, R. Ruth, *PRSTAB 13*, 060703 (*2010*)
G.Geloni *et al.* *DESY 10-033 (2010)*,
G.Geloni *et al.* *DESY 10-053 (2010)* (*Single-bunch*)

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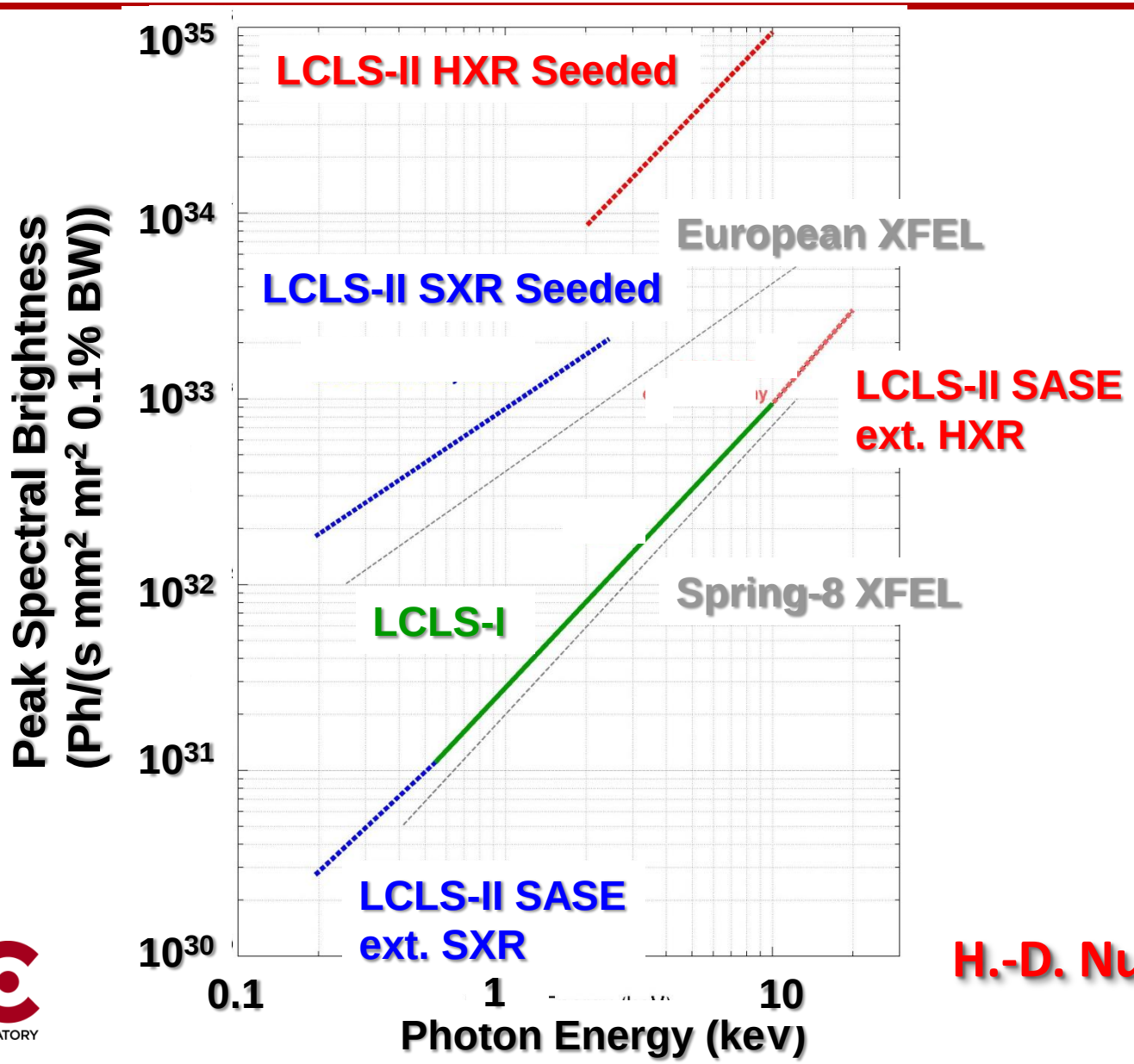
Peak Brightness of *LCLS*



H.-D. Nuhn

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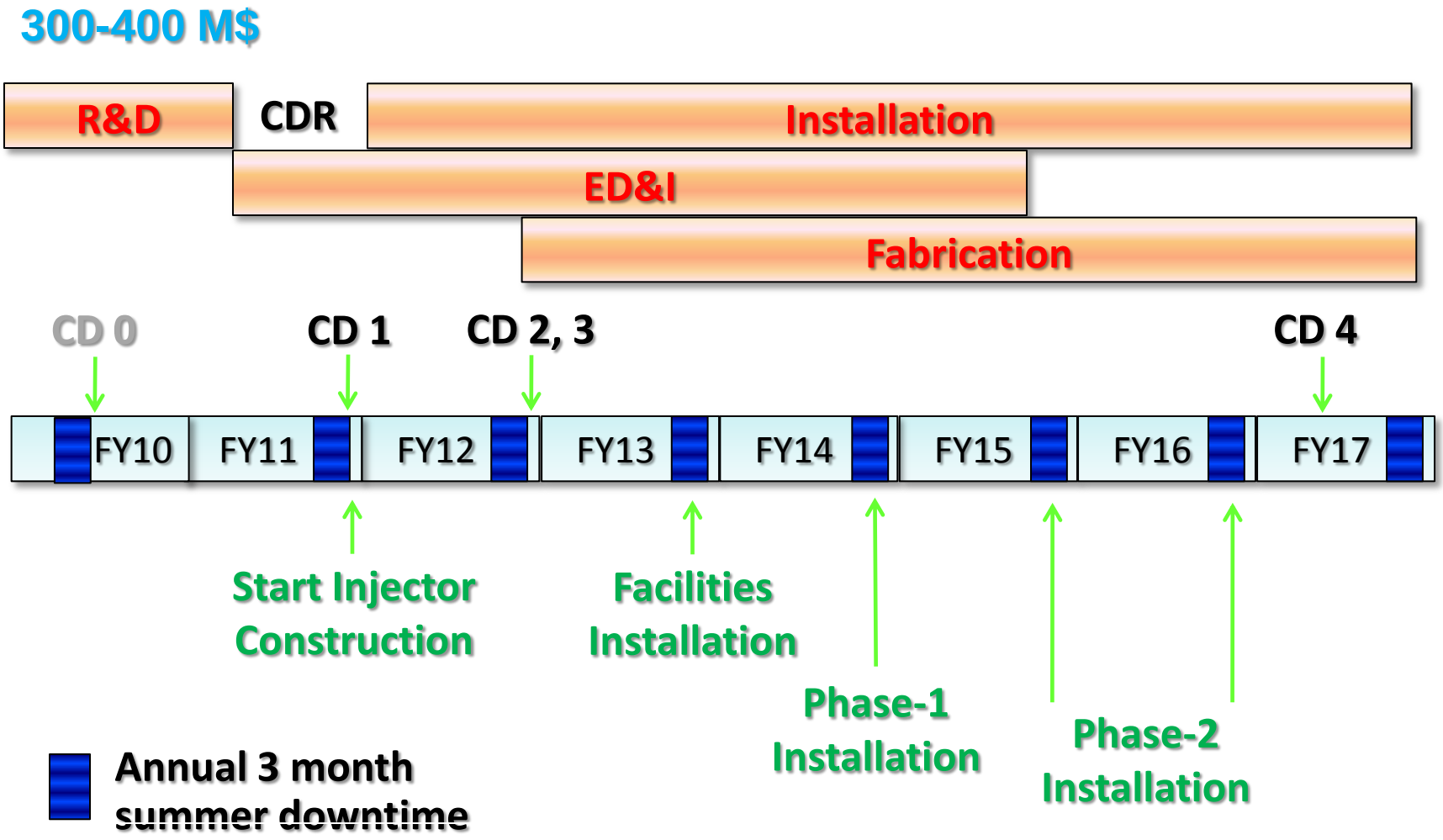
LCLS-II Timeline, Compatible with Operations



LCLS-II Summary

Soft X-Rays:

- 2-pulse, 2-color, variable delay (6-60 Å) using 1 e^- bunch or 2
- Self-seeding for narrow bandwidth (~10^{-4} at 6-60 Å)
- Full polarization control in SASE and self-seeded modes (fast & slow)
- 3-15 GeV bypass line allows simultaneous soft and hard x-ray operations in two separate beamlines with completely independent parameters
- Single femtosecond near-transform limited spike in low-charge mode

Hard X-Rays:

- Harder x-rays (0.62 Å) by modifying all undulators
- Few femtosecond pulses possible in low-charge mode
- Full polarization control
- Self-seeding with 2 electron bunches and short chicane (4 m) and 1 e^- bunch
- And… 22-30 GeV still possible using both 1-km linacs (+ 1st km still open)

Acknowledgement

- *This work was supported by United States of America Department of Energy under contract No. DE-AC02-76SF00515.*

- *Thanks to the committee for invitation*
- *Thanks to the LCLS team members*
- *Thanks for your attention*