LCLS Project Overview

- Controls Perspective

Patrick Krejcik

Bob Dalesio

15 GeV Electrons LCLS 1.5 Å X-Ray

Linac Coherent Light Source

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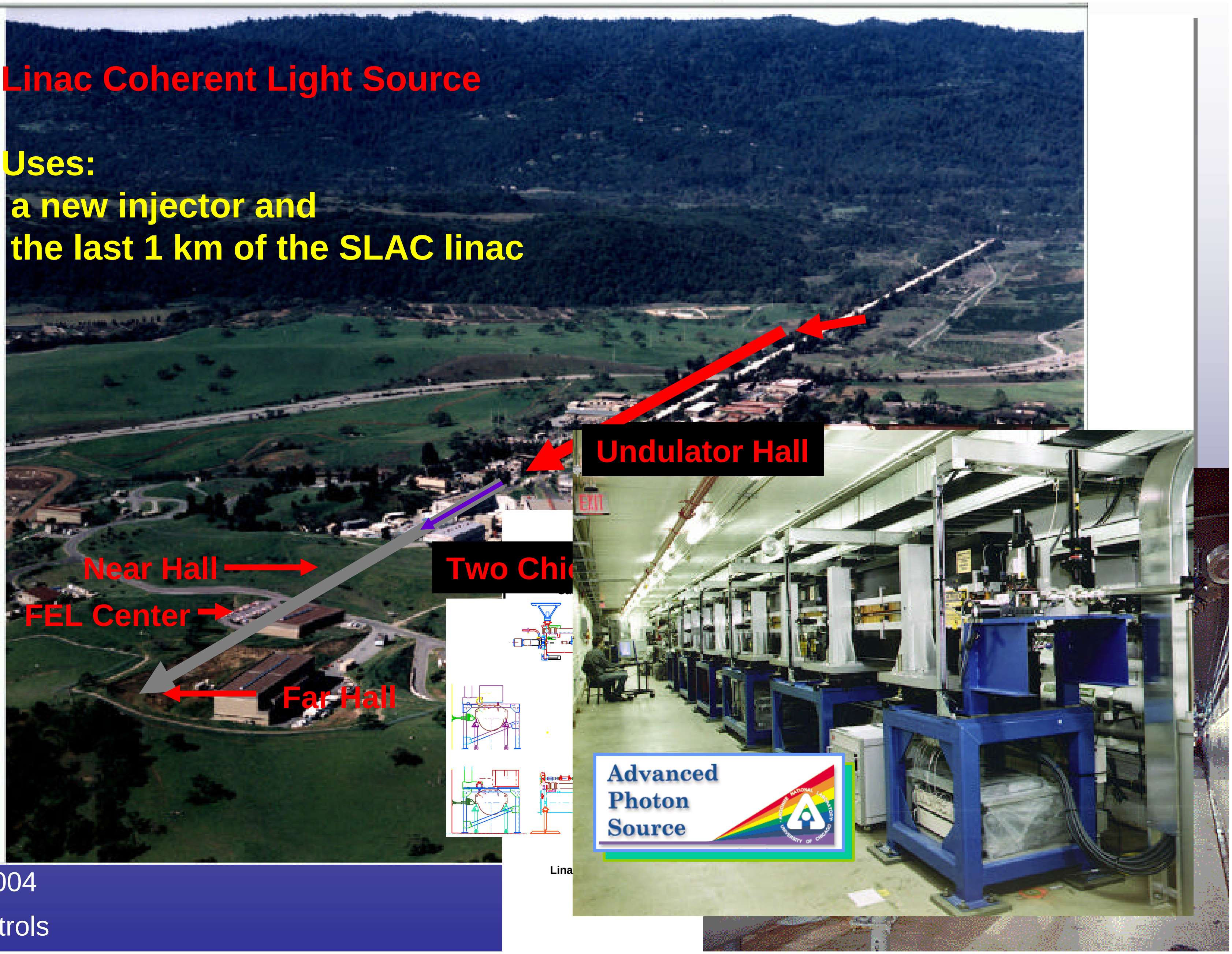
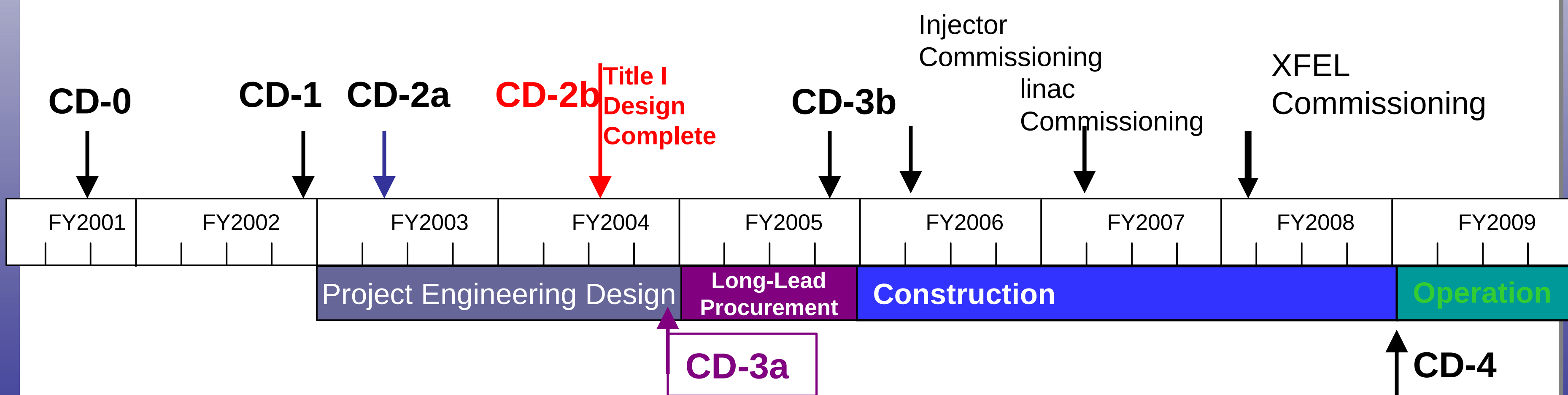
Uses:
a new injector and
the last 1 km of the SLAC linac



LCLS - Estimated Cost, Schedule

- *$273M Total Estimated Cost*
- *$315M Total Project Cost (PEPII was ~$180M)*
  - **FY2005** Long-lead purchases for injector, undulator
  - **FY2006** Construction begins
  - **FY2007** FEL Commissioning begins
  - ***September 2008*** Construction complete – operations begins



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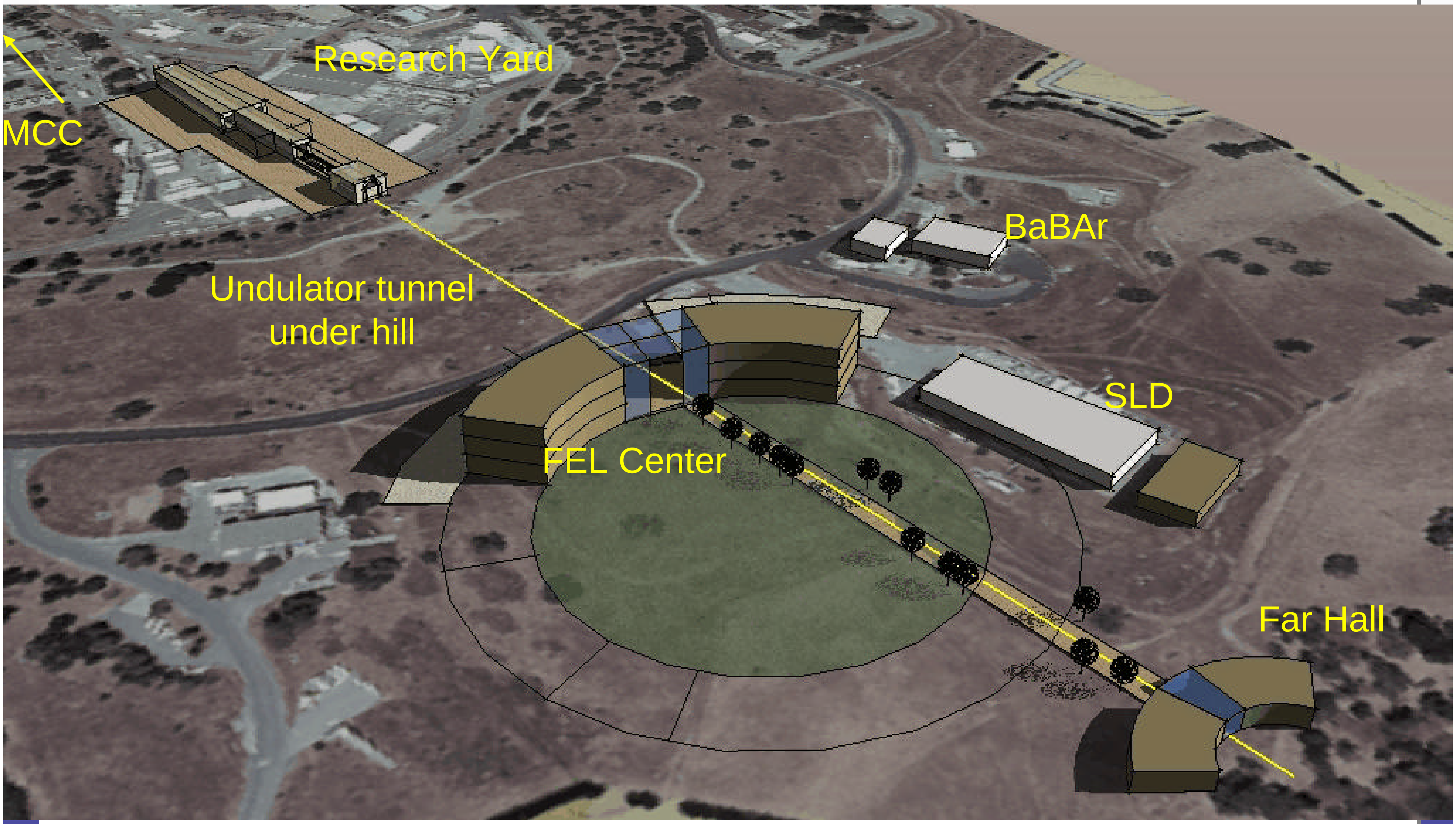
Research Yard
MCC
BaBAr
Undulator tunnel
under hill
SLD
FEL Center
Far Hall

The worlds first X-ray laser!

- "Conventional" laser cavities need mirrors
- But, mirrors don't work with x-rays
- So the laser "cavities" have to be stacked end to end and the photons make a single pass through a looong structure
- Atoms don't radiate at x-ray wavelengths, but high-energy electrons will *in an undulator*
- Free Electrons, NOW!

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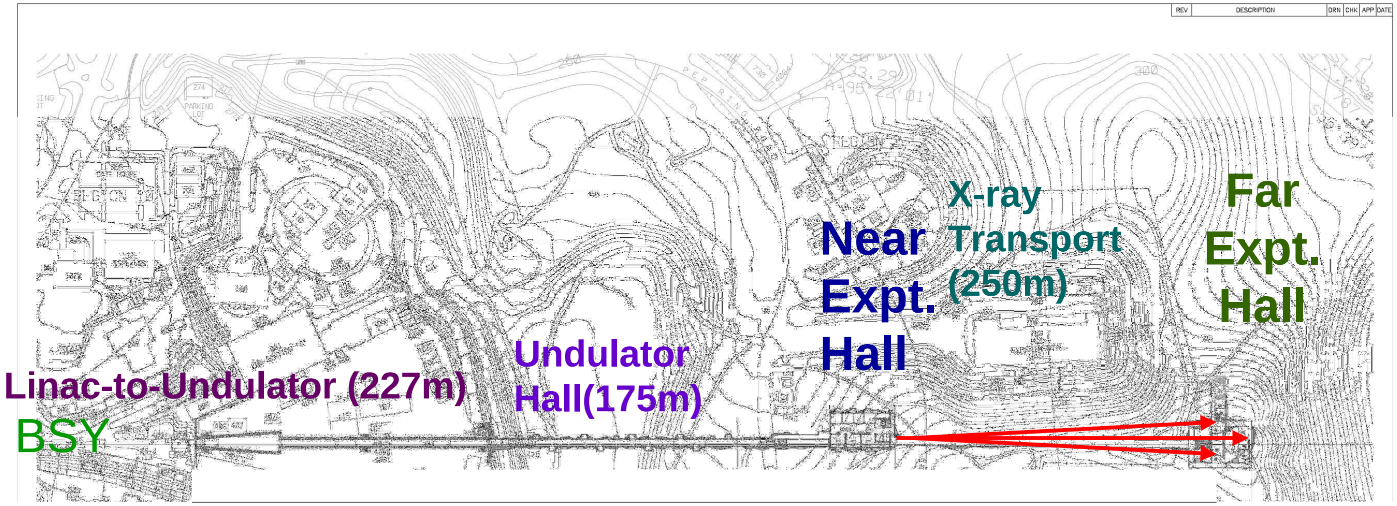

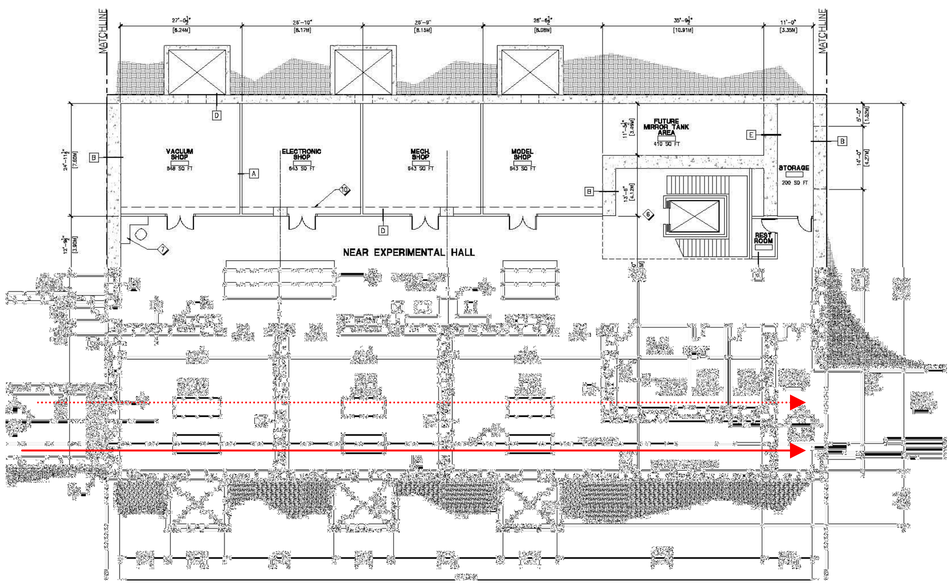

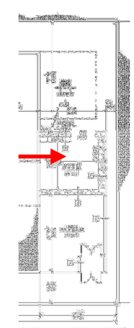

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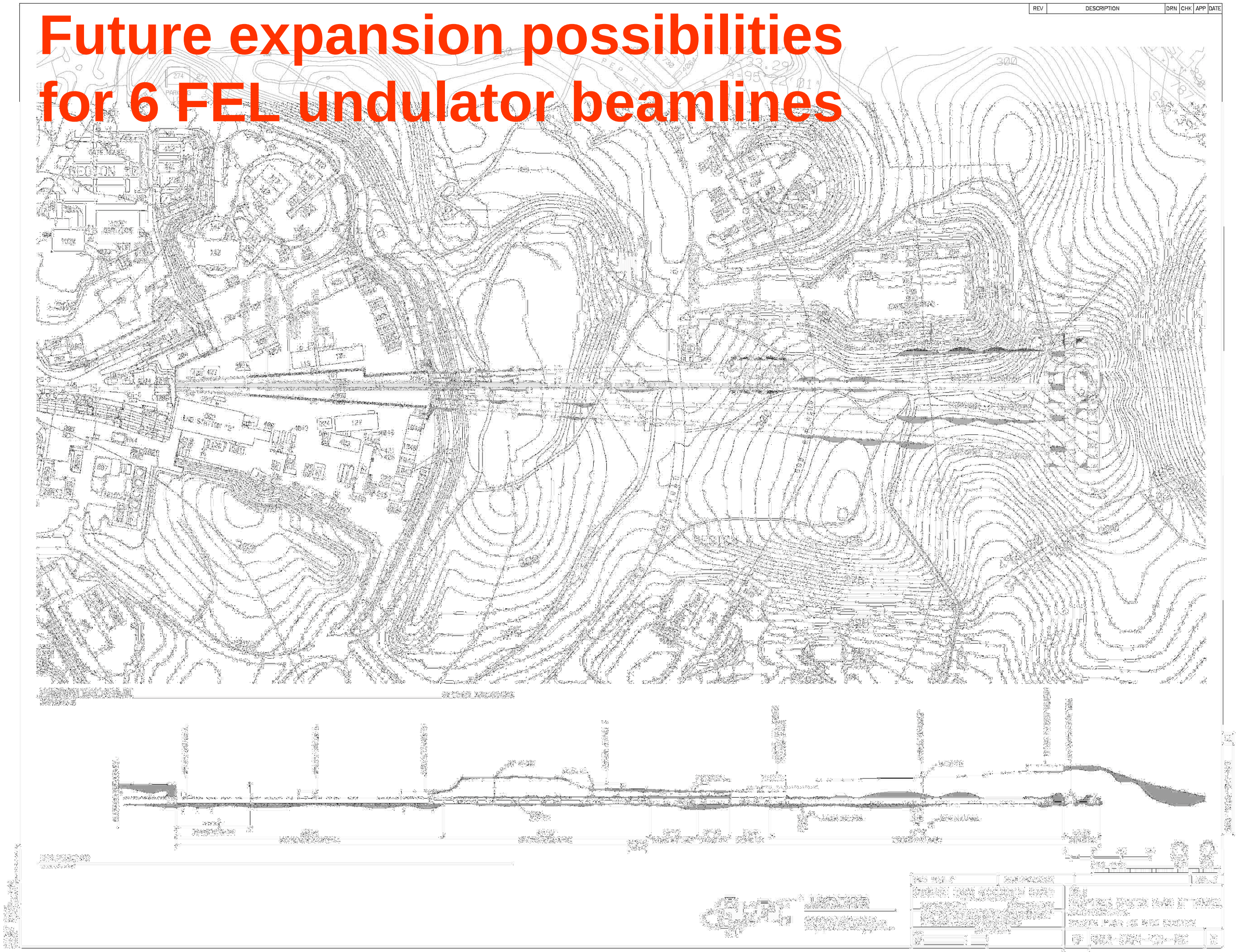
Future expansion possibilities for 6 FEL undulator beamlines



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What's special about a laser at x-ray wavelengths?

- At shorter wavelengths smaller details become visible
  - Like molecules and atoms
- Laser radiation is coherent, so 3D images can be created (of molecules!)
- The radiation will be 1,000,000,000,000 brighter than any other x-ray source
- That's enough photons to take an image of one molecule in one flash

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What's special about a laser at x-ray wavelengths?

- That one flash is very, very short, femtoseconds
- Freeze-frame images of molecular motion
- And capture the image before the sample vaporizes

- A whole new science waiting to be developed!

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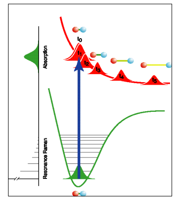
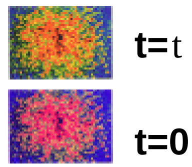
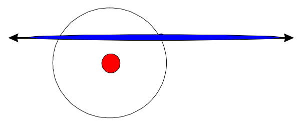
•SLAC-PUB-611

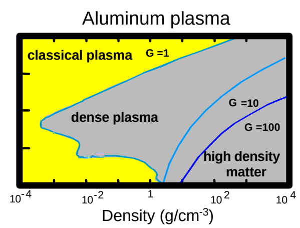
Program developed by international team of scientists working with accelerator and laser physics communities

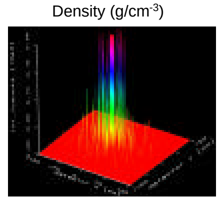
"the beginning.... not the end"











Femtochemistry

Nanoscale Dynamics in Condensed matter

Atomic Physics

Plasma and Warm Dense Matter

Structural Studies on Single Particles and Biomolecules

FEL Science/Technology

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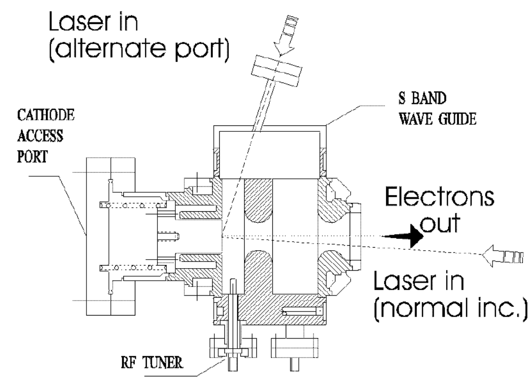
Technical Challenges - Injector



- Gun
  - normalized emittance
  - 120 Hz (power)
- Laser and cathode -120 Hz, spatial and temporal shaping
- Longitudinal Space Charge, CSR (Laser Heater)

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Key accelerator physics factors driving controls design

- Precision beams
  - low emittance, short bunch lengths
- Stringent stability requirements
  - Feedback control of
    orbit, charge energy and bunch length
- Single pass beams
  - unlike storage ring, every pulse potentially different
- Precision timing requirements

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Key facility factors driving controls design

- Undulator machine protection
  - Single pulse abort capability
- Compatibility with non-LCLS beams
  - Straight through beams some months of the year
  - Hybridize new controls with old SLC controls
  - LCLS controls can provide the upgrade path for the rest of the linac

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Design solutions for specialized diagnostics

- Low emittance beams require
  - Precision wire scanners
    - Average projected emittance
    - Almost non-invasive diagnostic
  - Profile monitor
    - Single pulse full beam profile
    - OTR screens inhibit *sase* operation
    - Low energy injector beams require YAG screens
  - Slice emittance reconstruction
    - Transverse RF deflecting cavity with profile monitor

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Design solutions for specialized diagnostics

- Short bunch, high peak current beams require
  - Longitudinal bunch profile measurement with sub-picosecond resolution
    - Transverse RF deflecting cavity
    - Electro optic bunch length measurement
  - A non-invasive bunch length monitoring system for pulse-to pulse feedback control
    - Spectral power detectors for CSR and CDR
  - A detector sensitive to micro-bunch instabilities
    - CSR spectrum

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Feedback global requirements

- Description of feedback types and locations
    - Orbit
    - charge
    - energy
    - bunch length
- Control system response time
    - 120 Hz single pulse data transfer, zero latency

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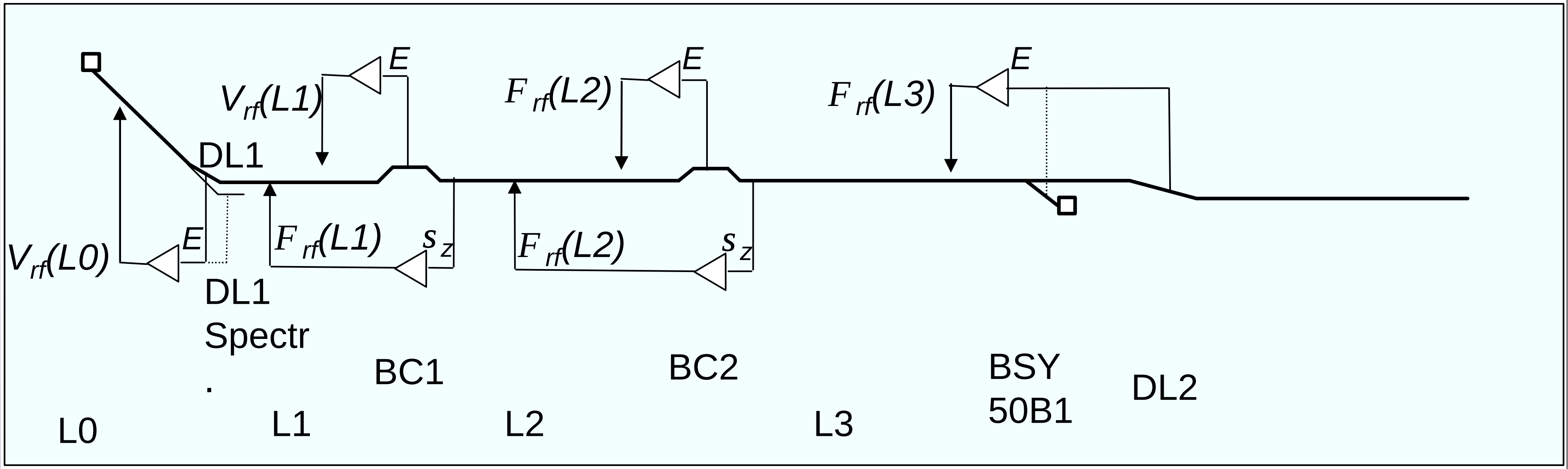
Energy and Bunch Length Feedback Loops



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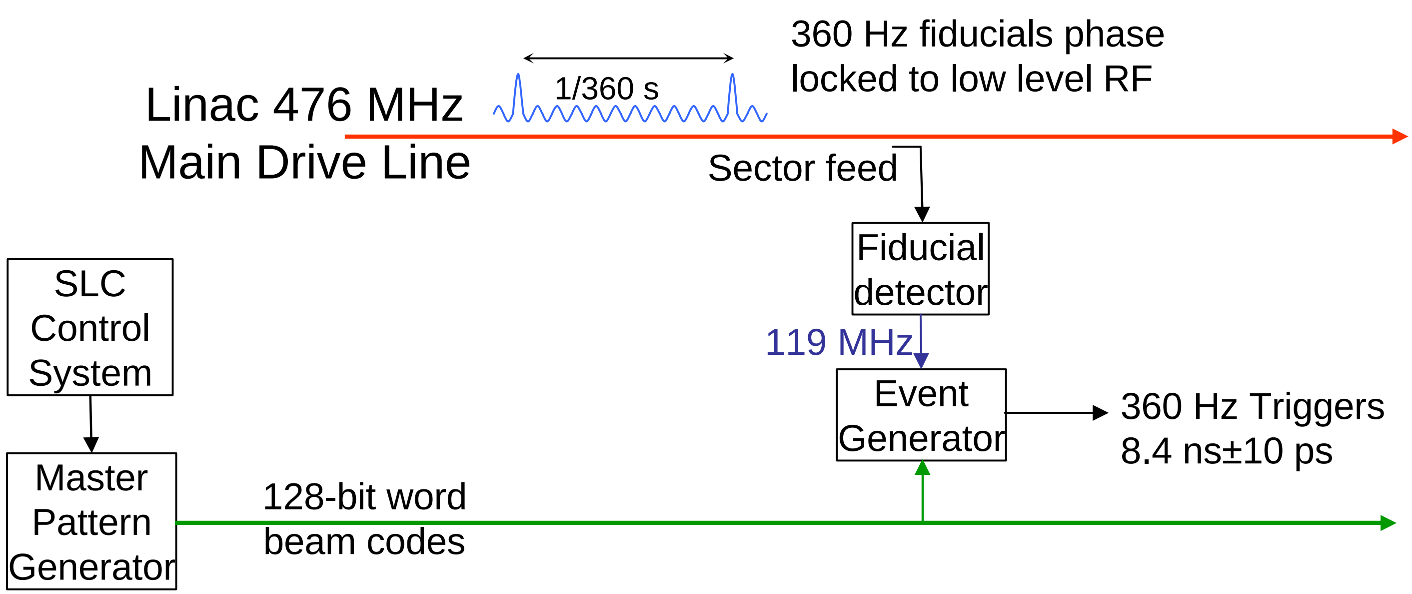
Timing system requirements

- Synchronization of fiducials in low-level RF with distribution of triggers in the control system



3 Levels in the Timing System

- "coarse" triggers at 360 Hz with 8.4 ns delay step size and 20 ps jitter
  - Gated data acquisition (BPMs)
  - Pulsed devices (klystrons)
- Phase lock of the low-level RF

  0.05 S-band (50 fs) phase stability
- Timing measurement of the pump-probe laser w.r.t. electron beam in the undulator

  10 fs resolution

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MPS - Beam Rate Limiting

- Single bunch beam dumper (SBBD)
  - Linac beam up to the dog-leg bend in the LTU can be maintained at 120 Hz
    - Favorable for upstream stability and feedback operation
  - Pulsed magnet allows
    - Single shot, 1 Hz, 10 Hz, 120 Hz down the LTU line
    - Failure in pulsed magnet will turn off beam at gun
- Tune-up dump at end of LTU
  - Max. 10 Hz to tune-up dump
  - Stopper out will arm MPS for stopping beam with the SBBD

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Technical Challenges- Linac

- Tight control on RF phase, amplitude
- Timing jitter, and its suppression
- We are learning a lot from SPPS
  - rms “fast” (>1 Hz) timing jitter <300fs,

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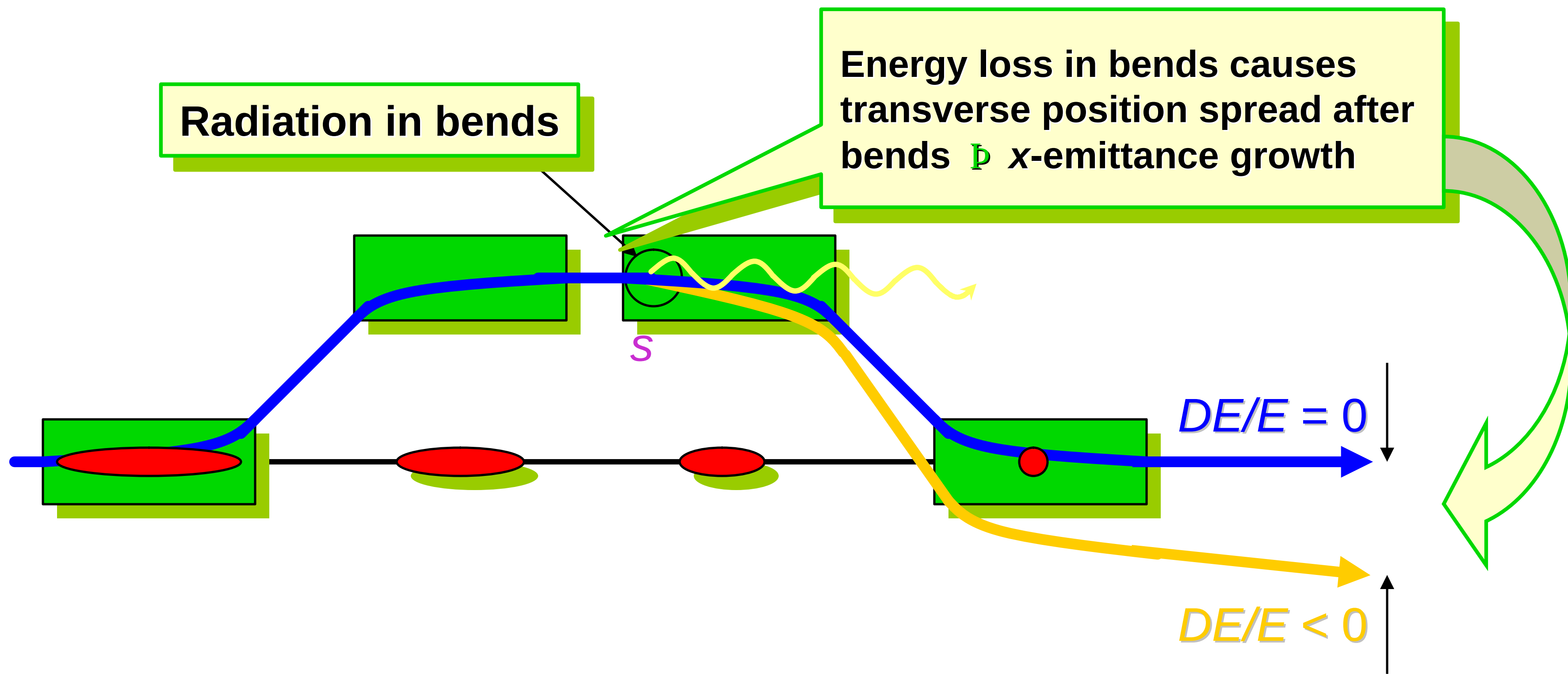
Coherent Synchrotron Radiation



CSR Effects ® Emittance Growth

Technical Challenges, Undulator

- 33 undulators within 0.015% of spec. field
- Undulator vertical alignment 50 microns
- Electron Trajectory walk-off within 2 microns
- Very low beam losses within undulators
- Commissioning strategy
  - Good diagnostics upstream of undulator
  - Diagnostics for electron channel

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Challenges – X-ray Transport/Optics/Diagnostics

- Extraordinary fluence, especially damaging at 1.5 nm
- Gas attenuator
- Diagnostics for x-ray beam transverse properties
- Diagnostics for x-ray pulse timing, jitter
- X-ray optics that can withstand the beam
  - photon wavelength selection
  - harmonic rejection filtering
  - split/delay
  - focus – to well below 1 micron spot

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