Issues and R&D Critical to the LCLS

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SLAC

UCLA

Stanford Linear Accelerator Center

Advanced Photon Source

SSRL

LLNL

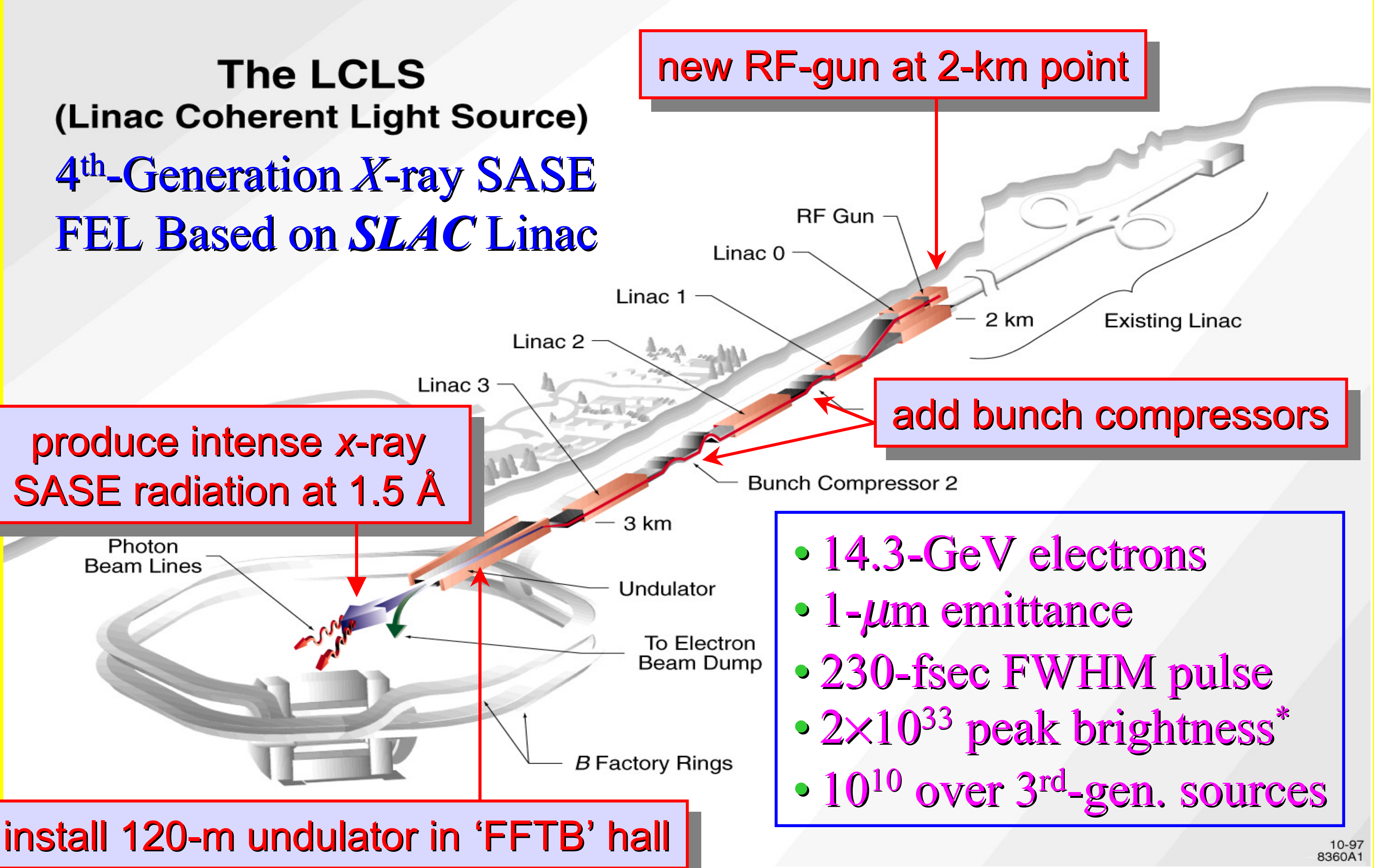
BROOKHAVEN NATIONAL LABORATORY

Los Alamos

15 GeV Electrons **LCLS** 1.5 Å X-Ray

Linac Coherent Light Source

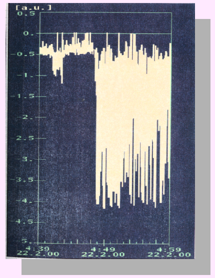
Linac Coherent Light Source (*LCLS*)



- 14.3-GeV electrons
- 1-μm emittance
- 230-fsec FWHM pulse
- 2×10^{33} peak brightness*
- 10^{10} over 3rd-gen. sources

* photons/sec/mm^2/mrad^2/0.1%-BW

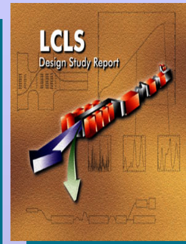
Other FEL-based sources being tested, built, or planned…



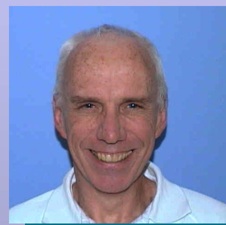
- **TESLA Test Facility (TTF) at *DESY***
  - ¬Lasing with gain ~3000 observed at 80-180 nm
- ***X*-ray TESLA FEL at *DESY* (associated with linear collider)**
  - ¬ TDR written
- **Source Development Laboratory (SDL) at *BNL*-NSLS**
  - ¬ Electron beam testing
- **Harmonic Generation (HGHG) successful at *BNL*-ATF**
- **VISA experiment at *BNL*-ATF**
  - ¬ Saturation achieved, March 2001
- **FEL's under study in Japan, Italy, England and Germany (BESSY II)**
- ***Low Energy Undulator Test Line (LEUTL) at ANL-APS***
  - ¬ ***High gain and saturation observed at 390 nm***

LCLS Project Update

- Design Study Report published 1998 (SLAC-R-521) led by Max Cornacchia



- New *LCLS* project leader at ***SLAC*** is John Galayda (formerly of ***ANL/APS***)

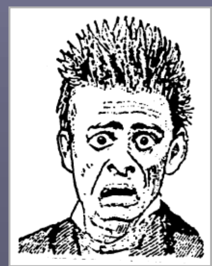


- *Critical Decision-0* (***CD-0***) approval was signed by DOE in June 2001

The U.S. Department of Energy

- Published plan for first 5 experiments (femto-chemistry, atomic physics, warm dense matter, …), Sep. 2000

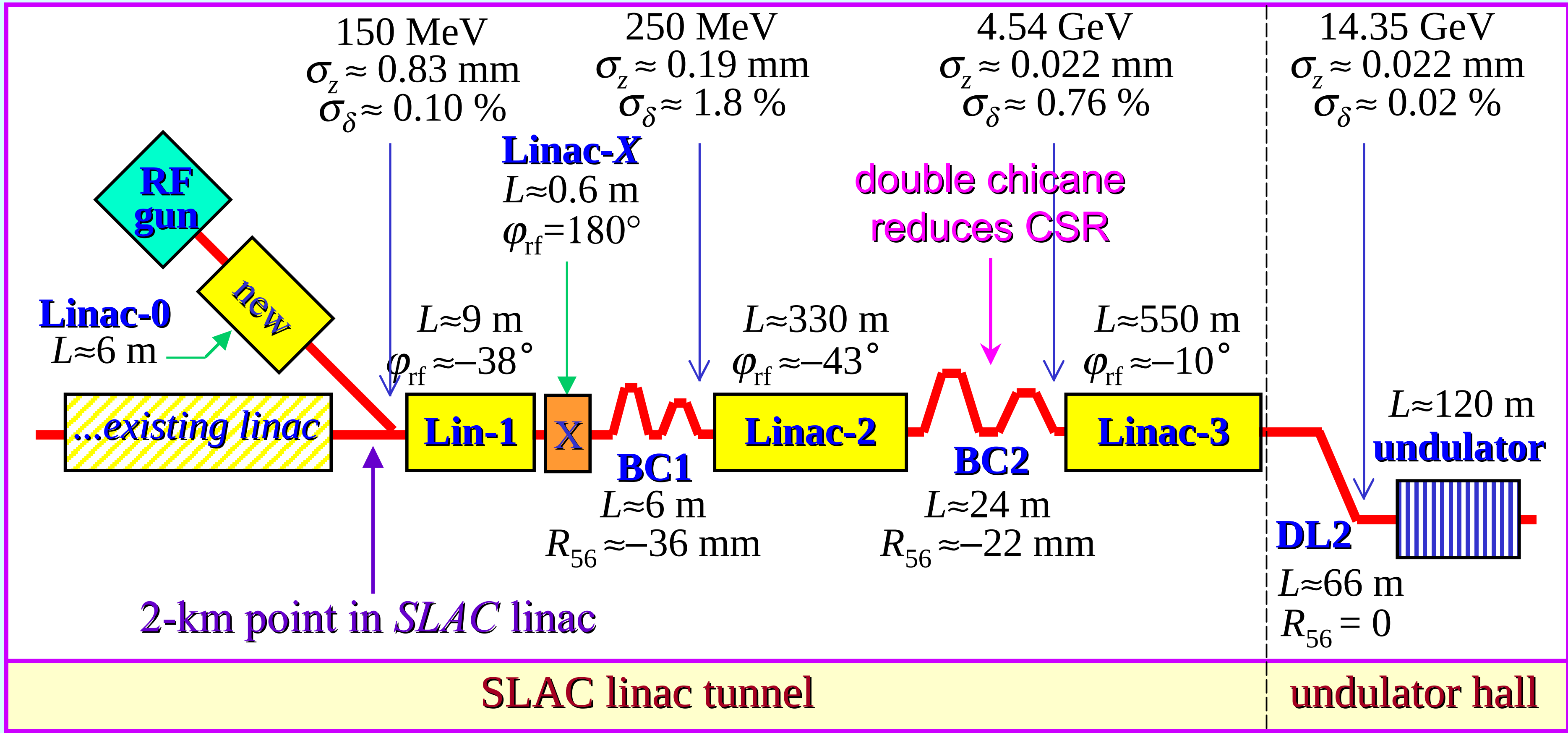
- Pre-engineering in 2003, construction in 2004, and operation in 2007



LCLS Issues and R&D

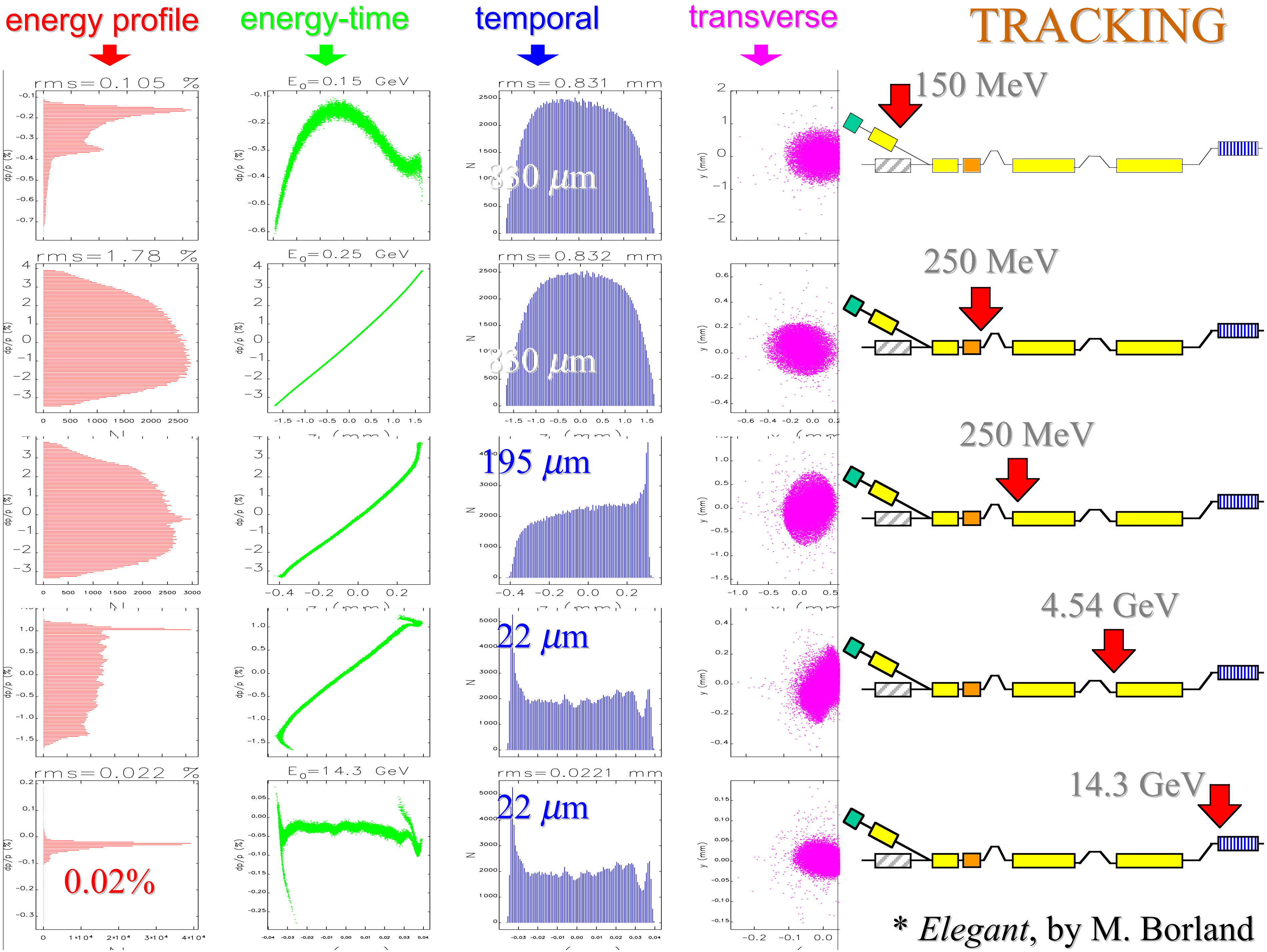
- Injector Requirements
  - $\gamma\varepsilon \leq 1$ μm at 1 nC and 100 A
  - Stability <1 psec timing & <2% charge
- Acceleration and Compression
  - ε-preservation → 'CSR' and wakefields
  - RF stability of 0.1°, 0.1% rms
- Undulator
  - Design, precise fabrication, and thermal stability
  - Trajectory alignment to <5 μm
  - Undulator wakefields
- X-ray optics

LCLS Acceleration and Compression



- Emittance control given coherent synchrotron radiation in bends
- Adequate machine stability (RF, charge, bunch-timing, …)

TRACKING



* *Elegant*, by M. Borland

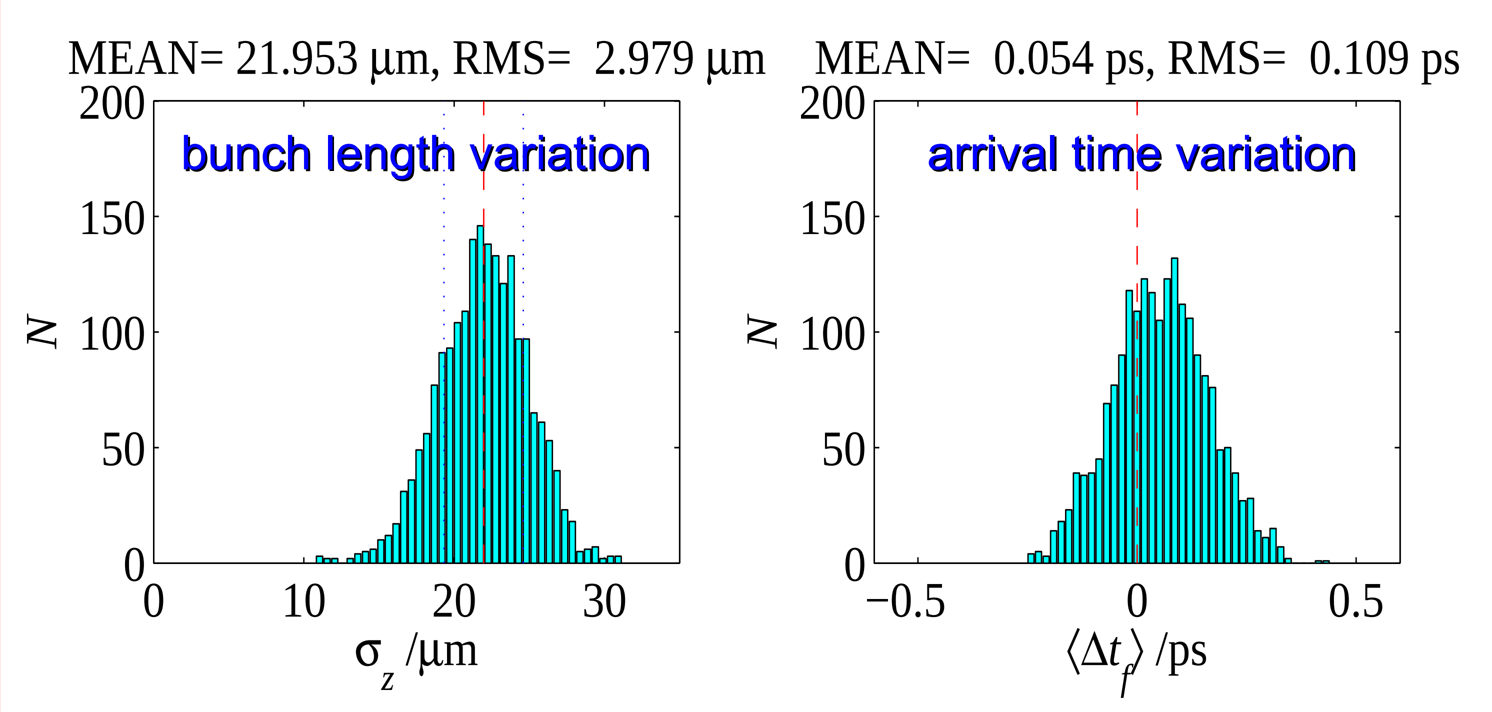
Stability Studies

Pulse-to-pulse 'jitter' estimates based on repeated tracking including parameter variations

- linac ⟨phase⟩ 0.1 deg-S rms
- linac ⟨voltage⟩ 0.1% rms
- Gun timing jitter 0.9 psec
- Charge jitter 2% rms

R. Akre, **TPAH105**

Track 100k macro-particles in long.-2D 2000 times with 'jitter'…

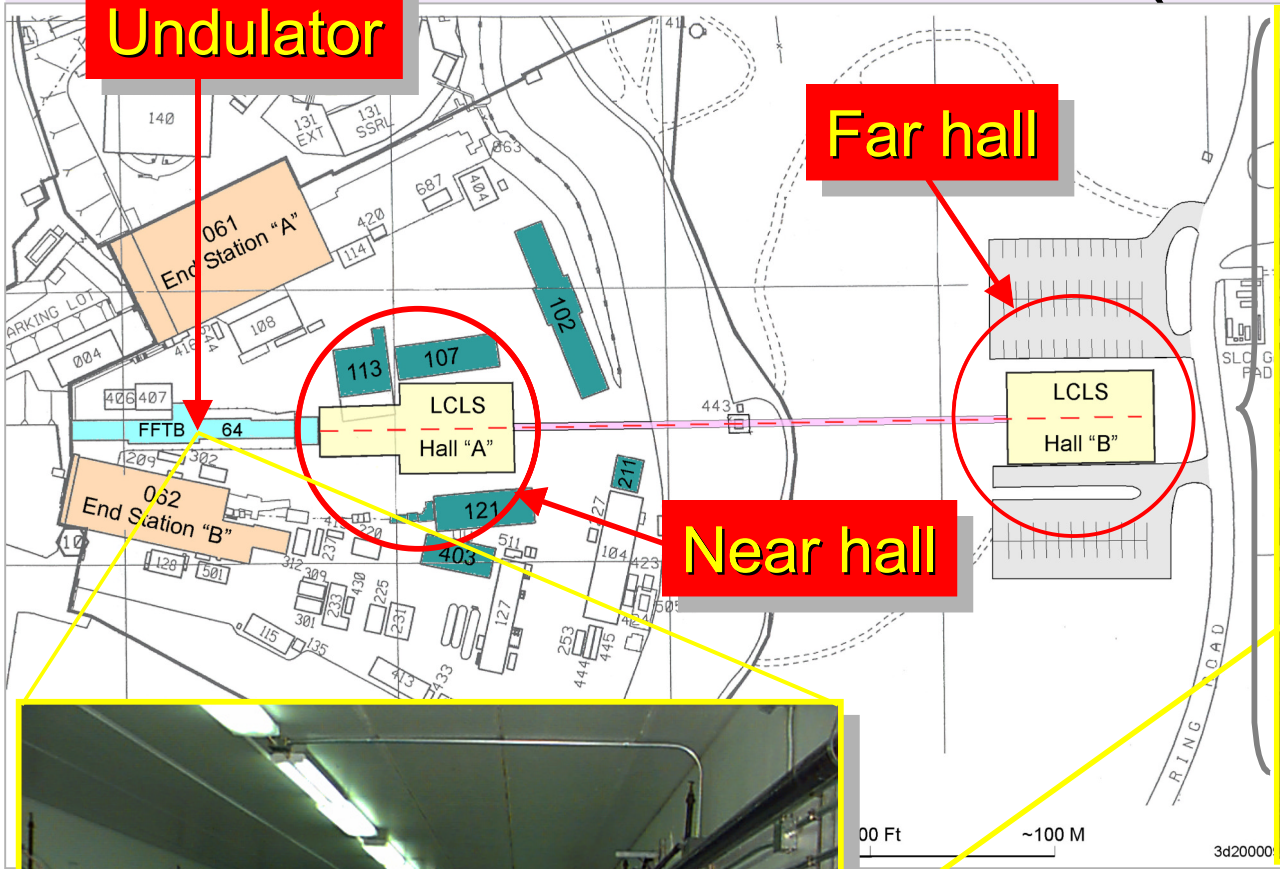


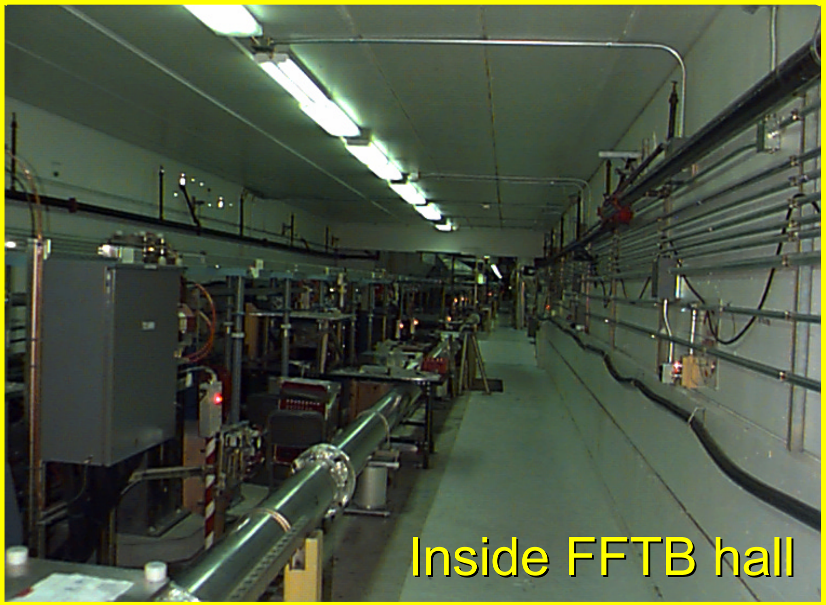
22 ± 3 μm rms

0 ± 109 fsec rms

More studies including CSR and 6D tracking in… M. Borland, **WPPH103**

Undulator Hall (FFTB)





Install 122-m long planar undulator in existing FFTB hall

Undulator (ANL/APS)

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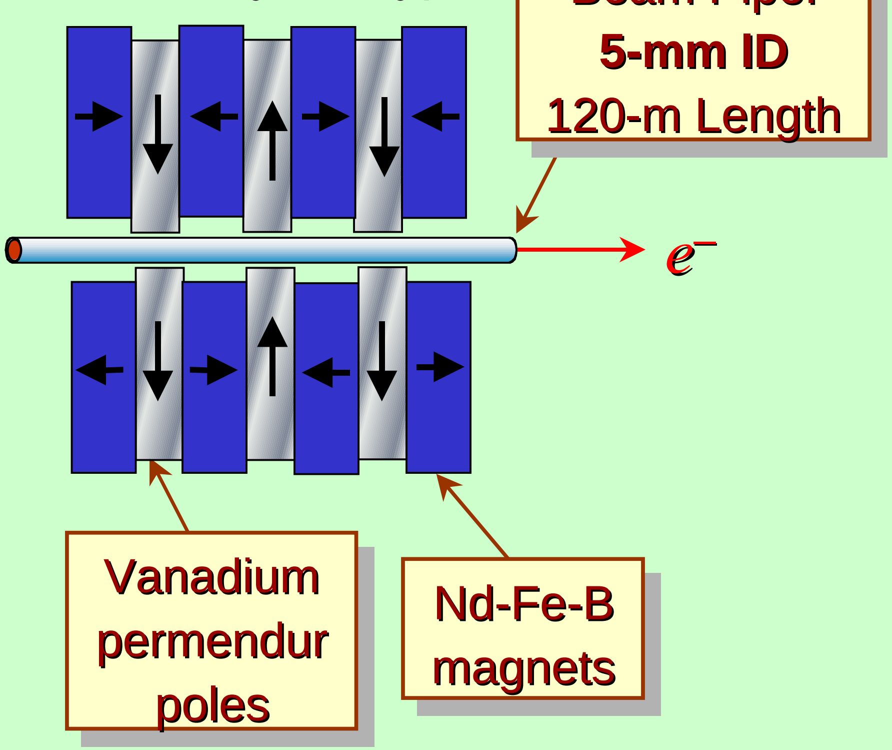
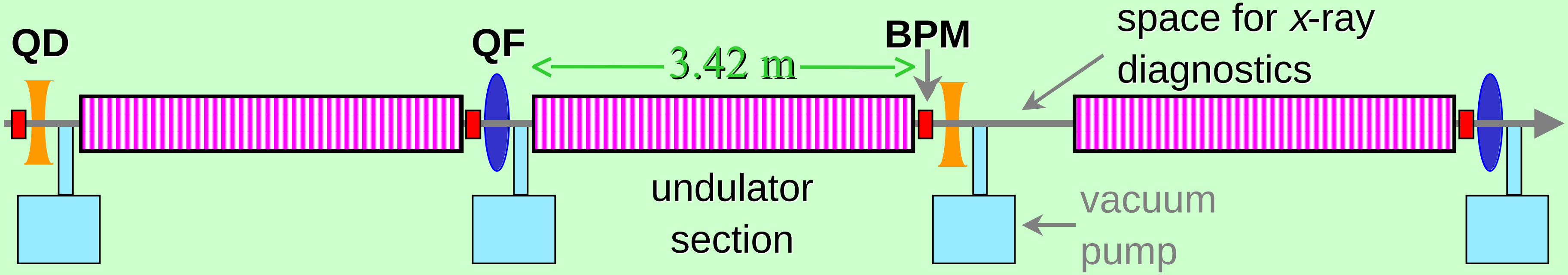
Planar hybrid type



undulator line length	122	m
undulator period, λ_u	30	mm
undulator parameter, K	3.71	
undulator section length	3.42	m
magnetic gap height	6.0	mm
No. of undulator sections	33	
break length (short)	0.19	m
break length (long)	0.42	m

1-μm BPM → cavity and button-type in compact package (G. Decker, ***ANL***)



Quad-magnets and undulator sections on independent movers

E. Moog, **TOPA012**

LCLS 9-Pole Prototype Undulator (ANL)

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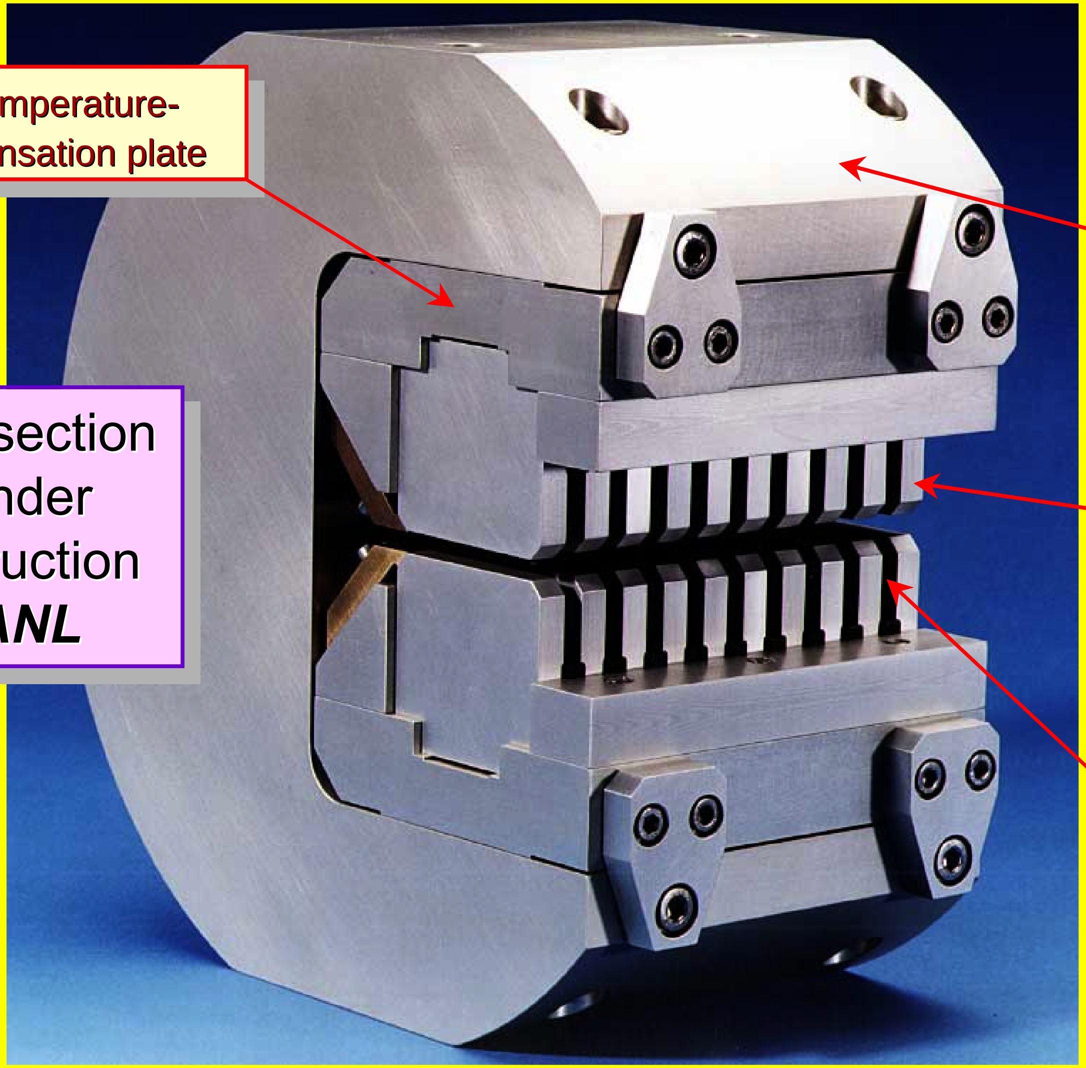


Al temperature-compensation plate

Titanium strong-back

Va permendur poles

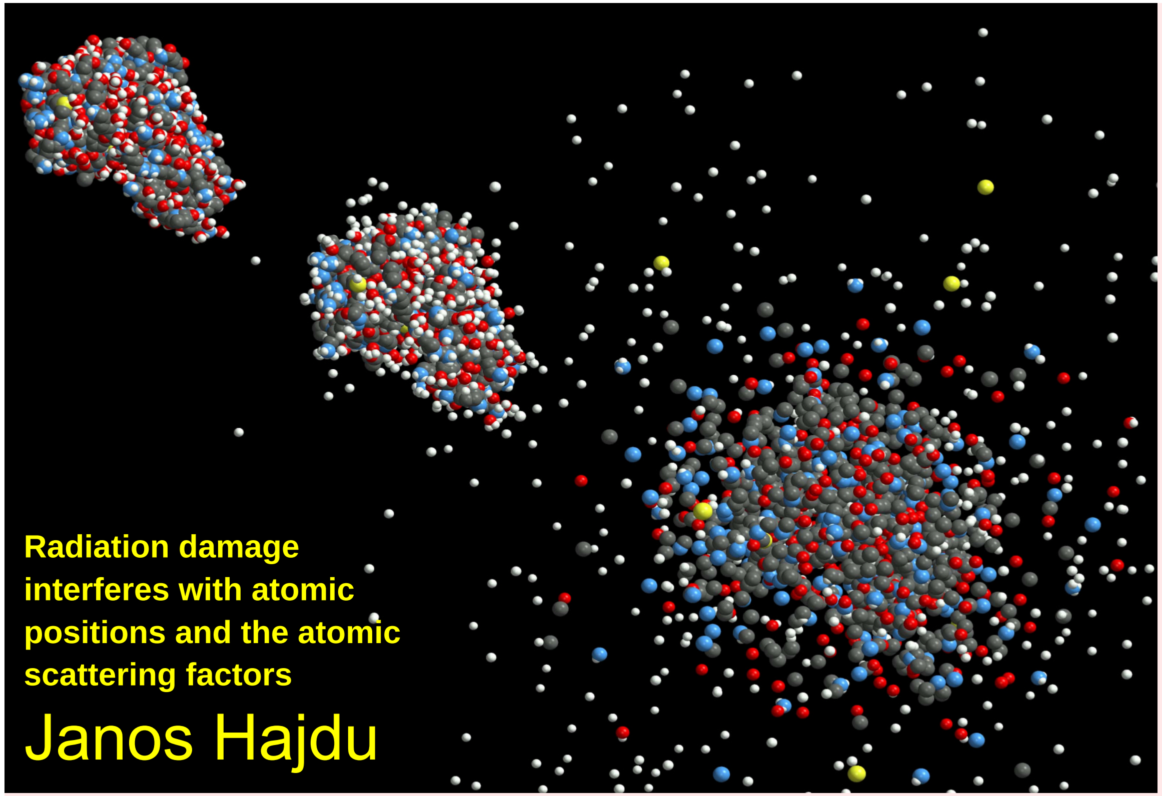
Nd-Fe-B magnets

3.4-m section is under construction at ***ANL***

Courtesy E. Gluskin, *ANL*

E. Moog, **TOPA012**

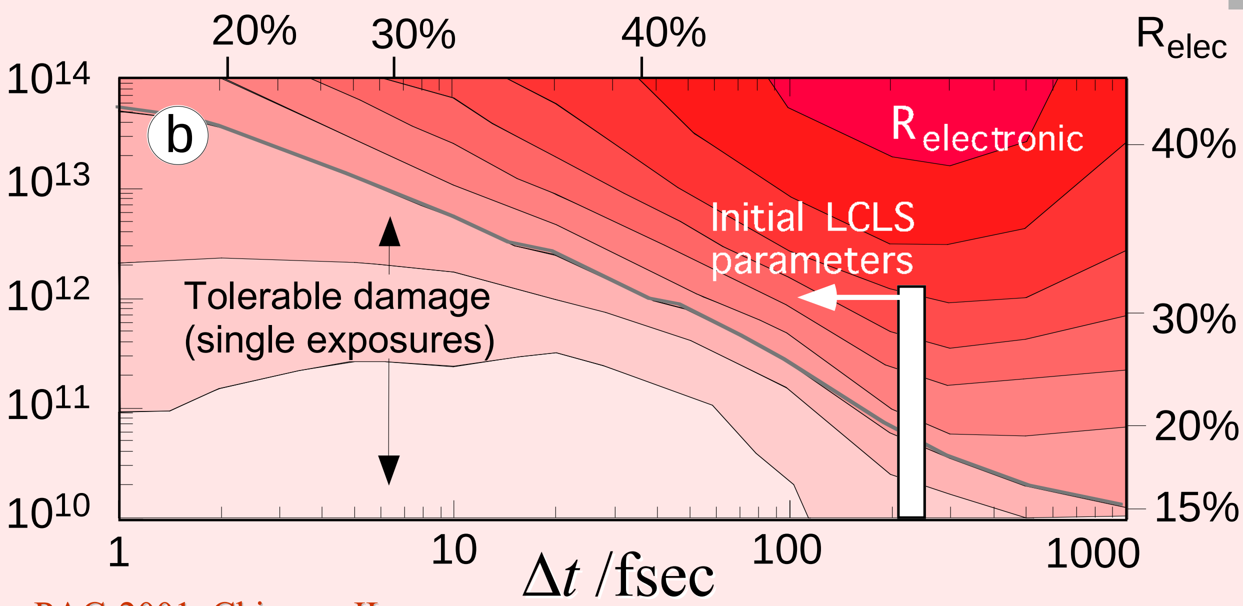
Motivation for even shorter *x*-ray pulses



Coulomb Explosion of Lysozyme (50 fs)

Further e^- compression difficult:

- CSR in bends
- Undulator wakefields

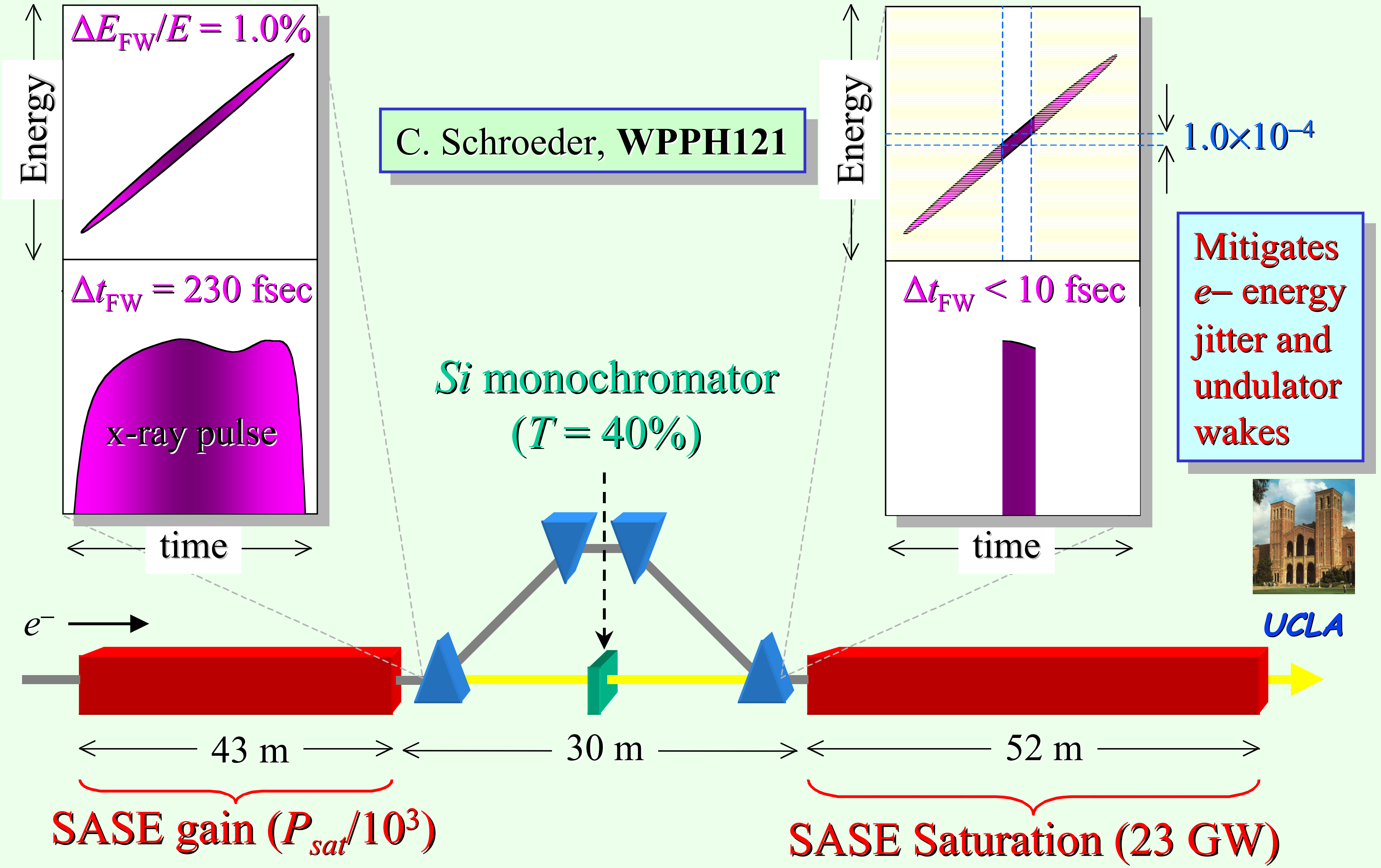


Compress *x*-ray pulse with chirp & slicer (R. Bionta, ***LLNL***)

…or…

Two-stage undulator for shorter pulse

C. Schroeder, **WPPH121**



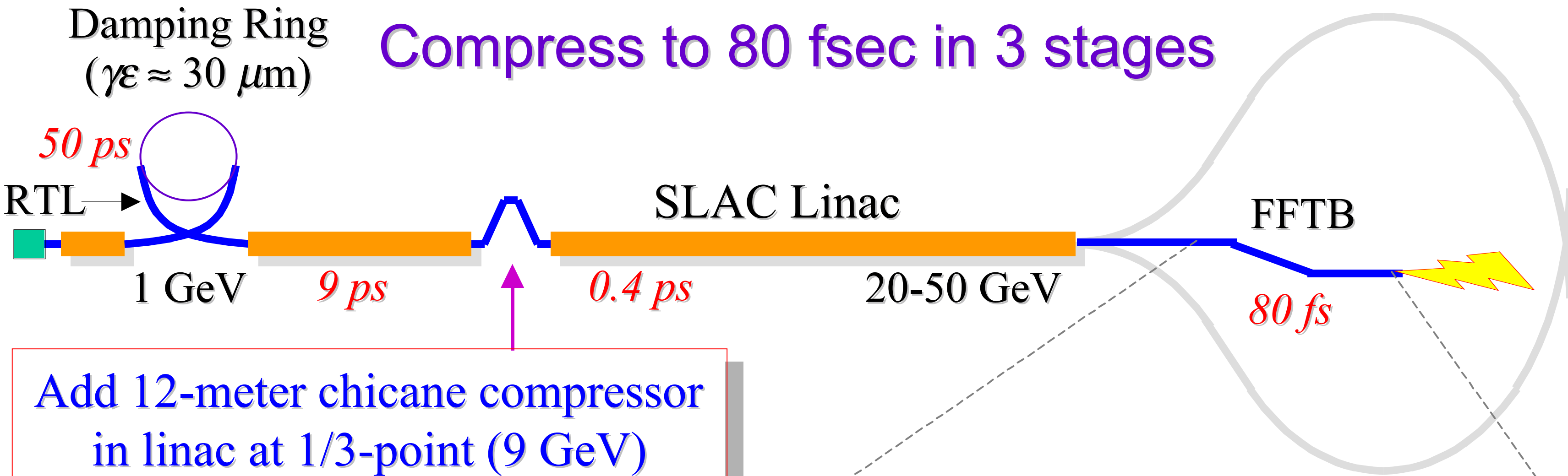
Mitigates *e*– energy jitter and undulator wakes

PAC-2001, Chicago, IL

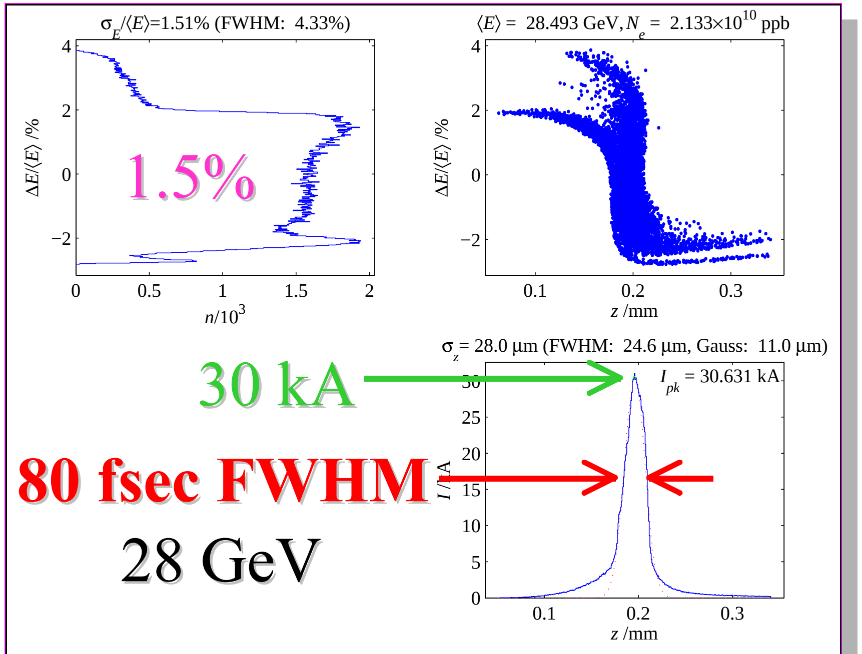
Also a ***DESY*** scheme which emphasizes line-width reduction (B. Faatz)

Short Bunch Generation in the SLAC Linac

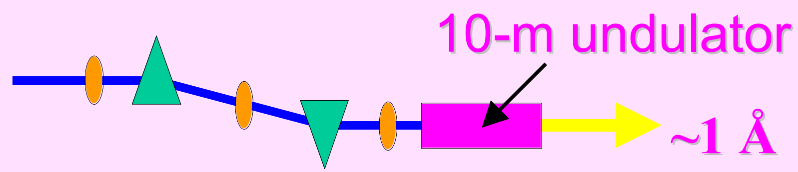
Compress to 80 fsec in 3 stages



Add 12-meter chicane compressor in linac at 1/3-point (9 GeV)



Existing bends compress to **<100 fsec**



Add to understanding of CSR and *X*-ray optics

P. Emma, **FPAH165**

Summary of Key Issues

- Emittance generation and preservation
  - ♦ Gun $\gamma\varepsilon \approx 1\ \mu\mathrm{m}$, repeatable at 120 Hz
  - ♦ Need better understanding of CSR
- Stable operation
  - ♦ RF, laser, and feedback systems
- Undulator errors and trajectory control
  - ♦ Fabrication, alignment, and BPMs
  - ♦ Wakefields
- SASE saturation at ~1Å