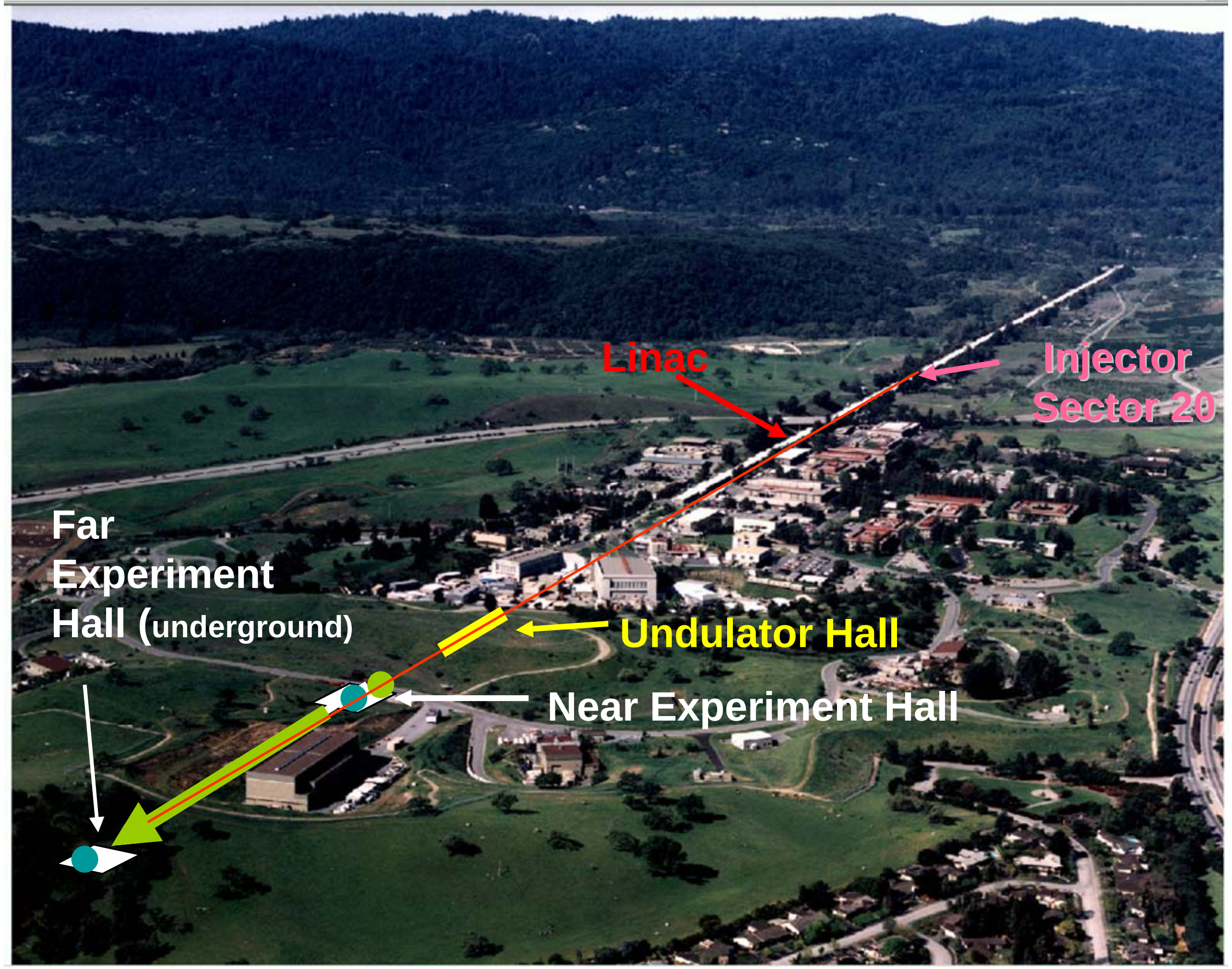
Status & Challenges for LCLS

David H. Dowell
Stanford Linear Accelerator Center
(on Behalf of the LCLS Team)

Free Electron Laser Conference
Berlin, Germany
August 2006

- Status of LCLS Construction
- Overview of the Challenges
- Schedule
- Summary

The LCLS will use the last 1/3 of the SLAC linac to create an x-ray FEL



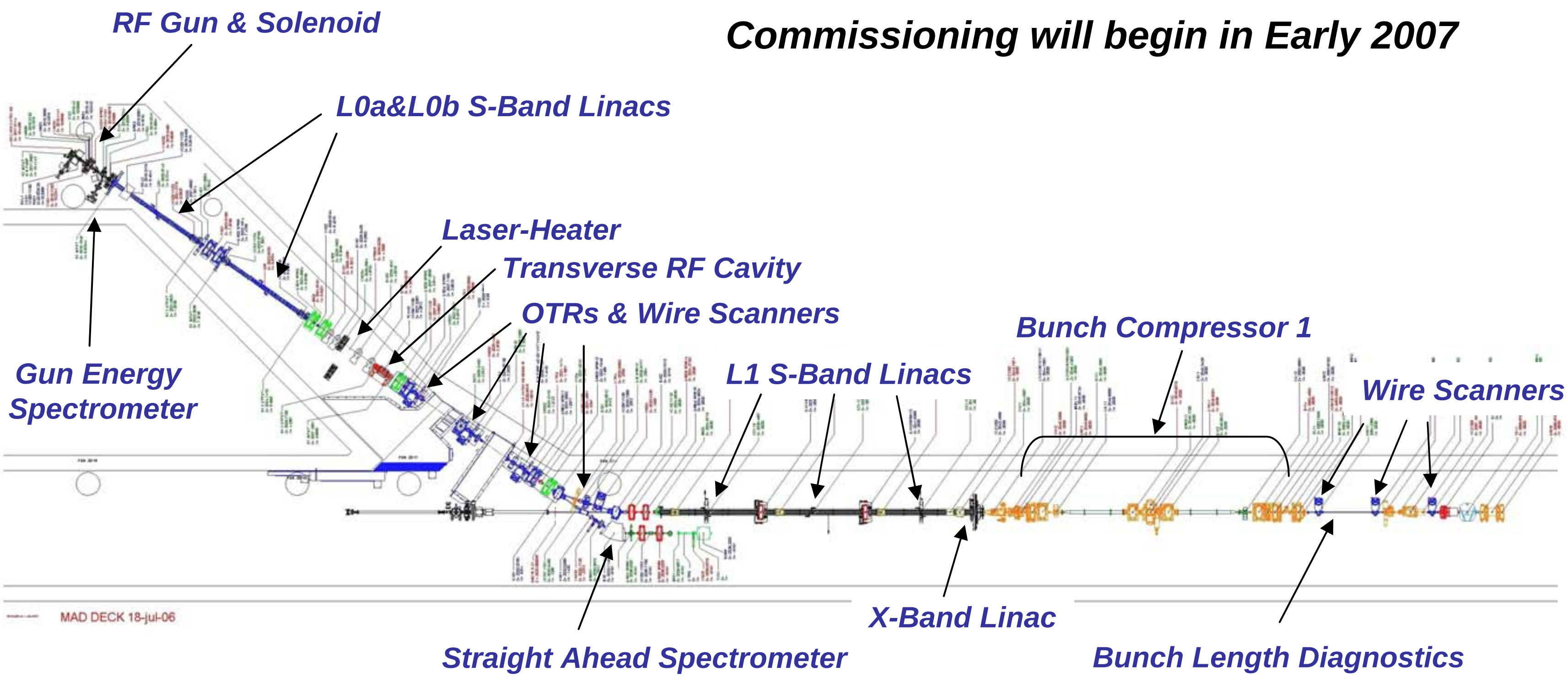
LCLS Design Parameters

Fundamental FEL Wavelength	**1.5**	**15**	Å
Electron Beam Energy	13.6	4.3	GeV
Normalized Slice Emittance (rms)	1.2	1.2	mm-mrad
Peak Current	3.4	3.4	kA
Energy Spread (slice rms)	0.01	0.03	%
Bunch/Pulse Length (FWHM)	≤ 200	≤ 200	fs
Saturation Length	87	25	m
FEL Fundamental Power @ Saturation	8	17	GW
FEL Photons per Pulse	1	29	10^{12}
Peak Brightness @ Undulator Exit	0.8	0.06	10^{33} *

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

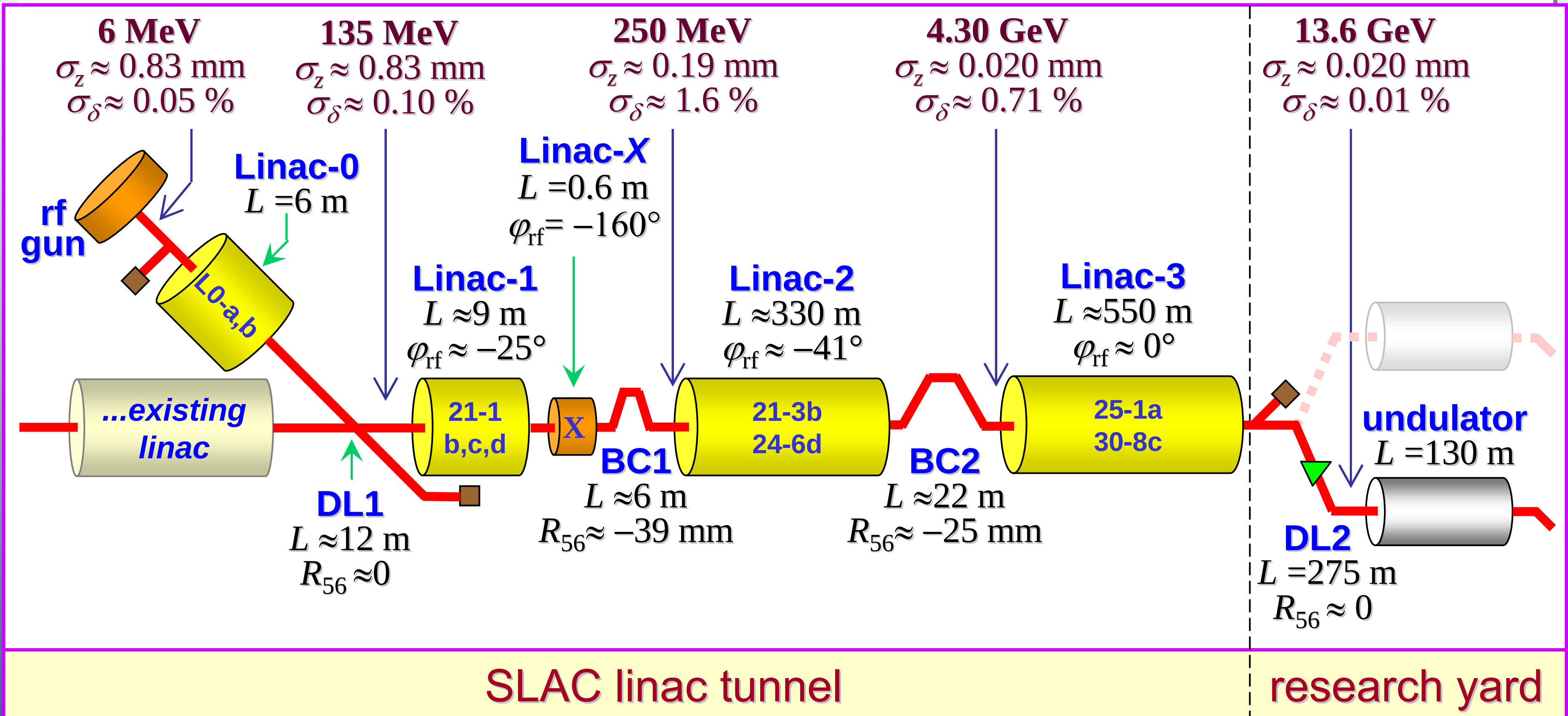
Injector and Bunch Compressor 1 Installation is in Progress at Sectors 20 and 21

Commissioning will begin in Early 2007



David H. Dowell
dowell@slac.stanford.edu

LCLS Accelerator and Compressor Systems



BC1 Chicane Support and Translation Stage

David H. Dowell
dowell@slac.stanford.edu


Spectrometer Dipole

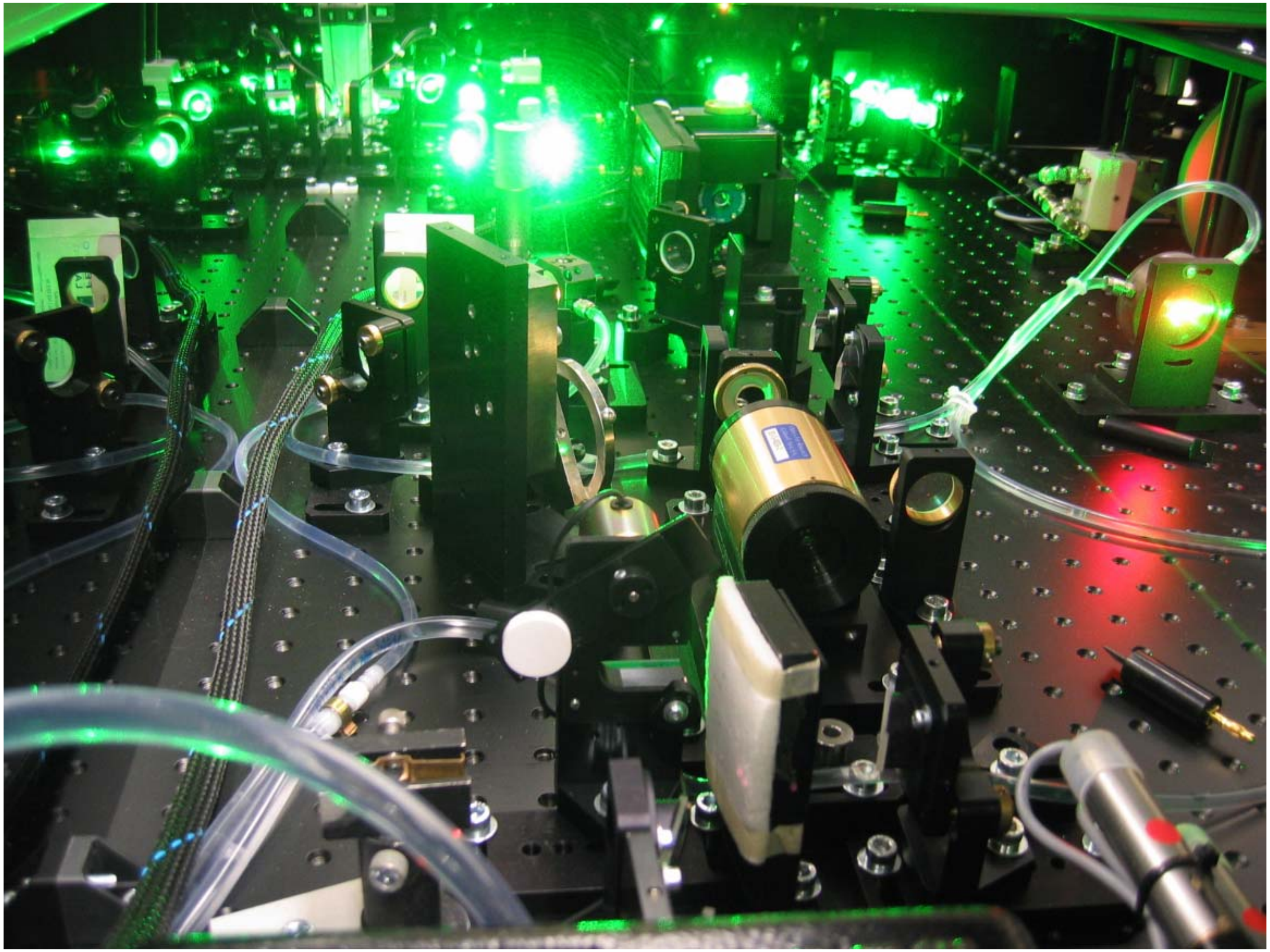

Dog-Leg-1 Dipole


Gun-Spectrometer
Quadrupole


Injector Quadrupoles

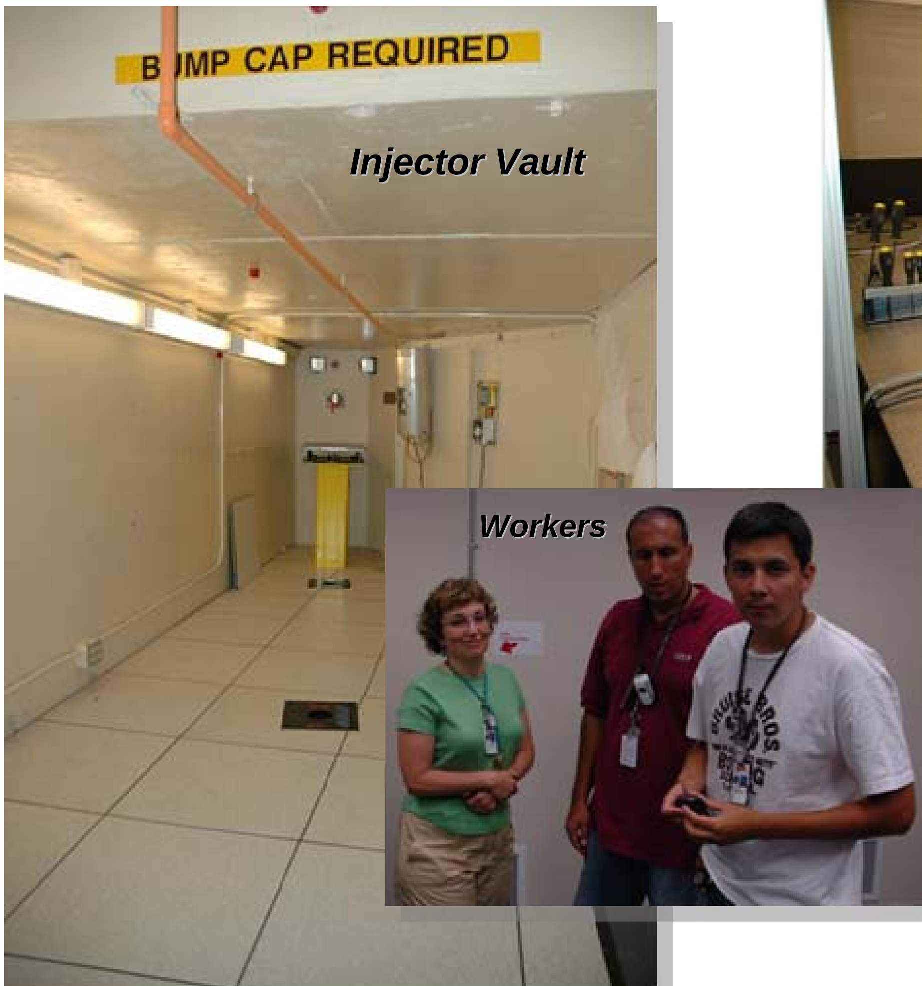

Injector Solenoid #2

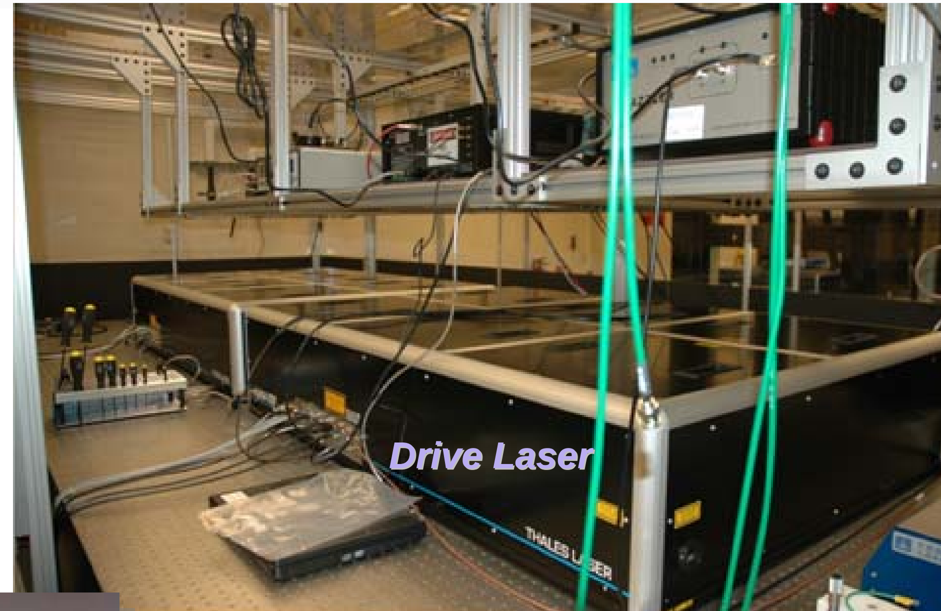
Cathode Drive Laser Operating at Sector 20



David H. Dowell
dowell@slac.stanford.edu

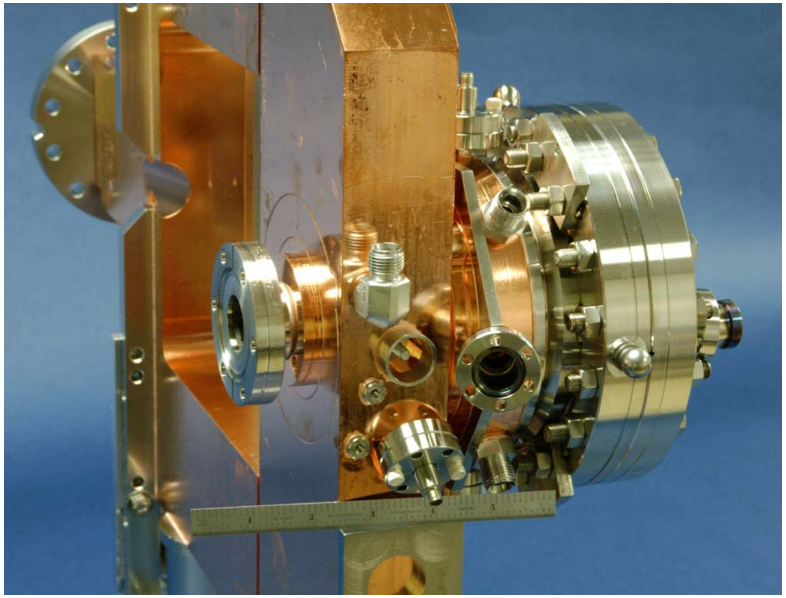
Drive Laser Installed & Vault Ready for Installation

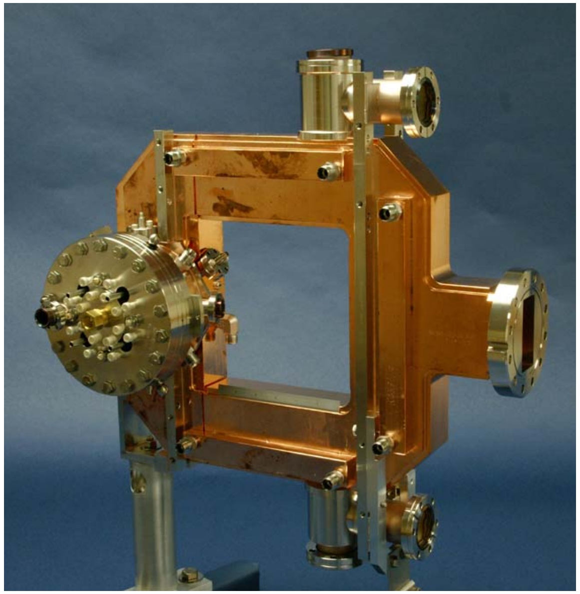


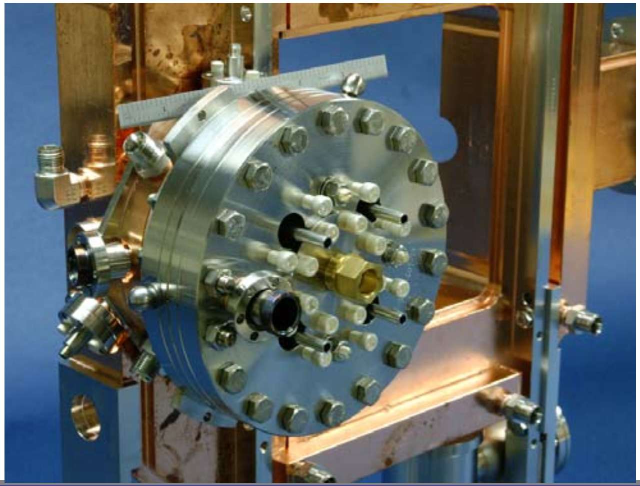


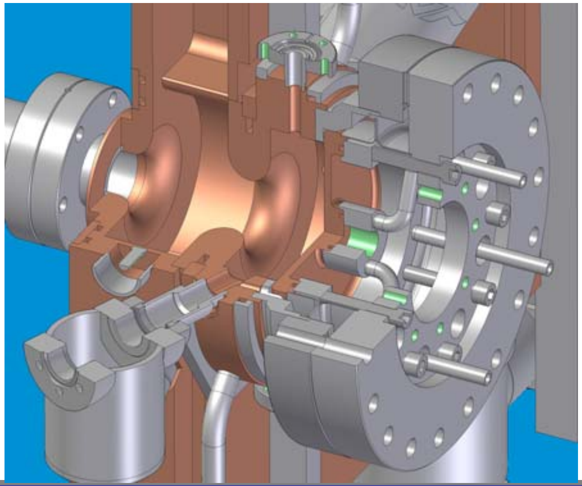
David H. Dowell
dowell@slac.stanford.edu

RF Gun Fabrication and Cold RF Testing Finished & Preparing for High-Power Tests





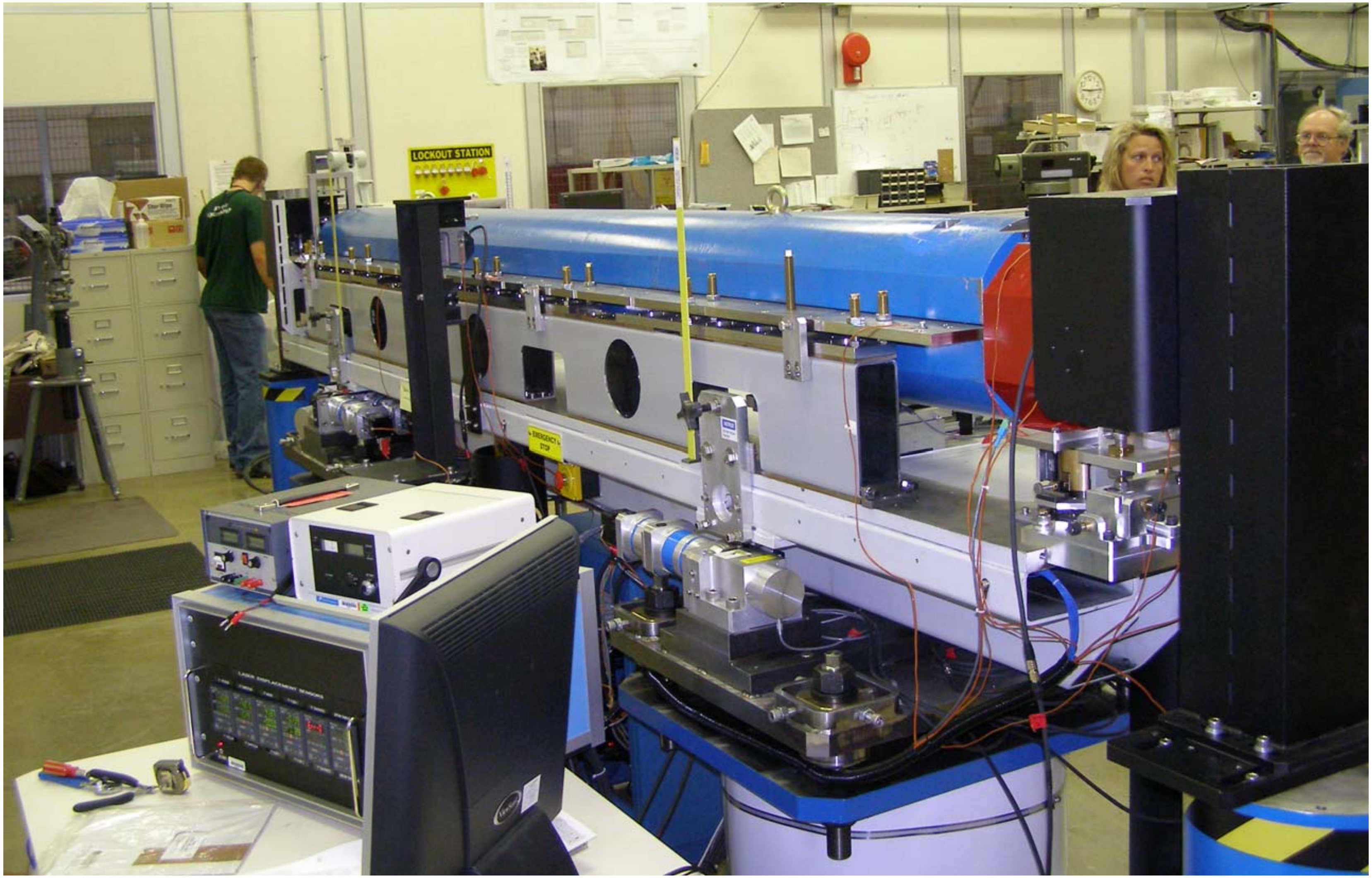




David H. Dowell
dowell@slac.stanford.edu

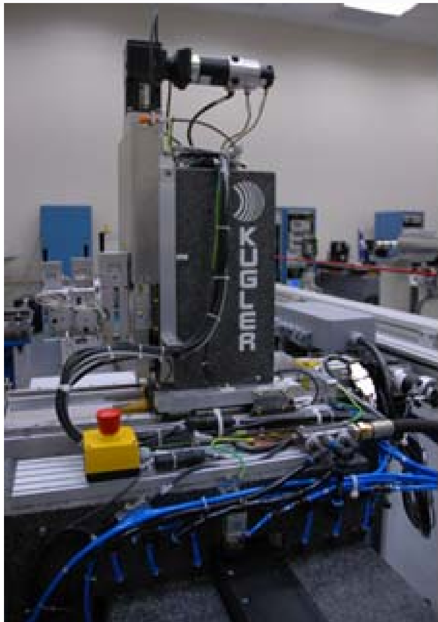
Klystron Gallery at S20 Looking Toward the Undulator and End Stations

Single Undulator Test (SUT) at ANL

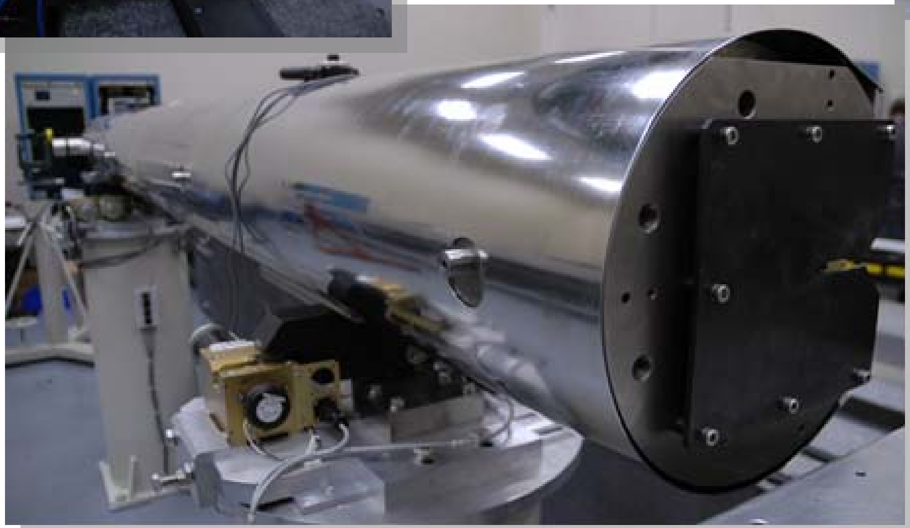


David H. Dowell
dowell@slac.stanford.edu

New Magnetic Measurements Facility (MMF)



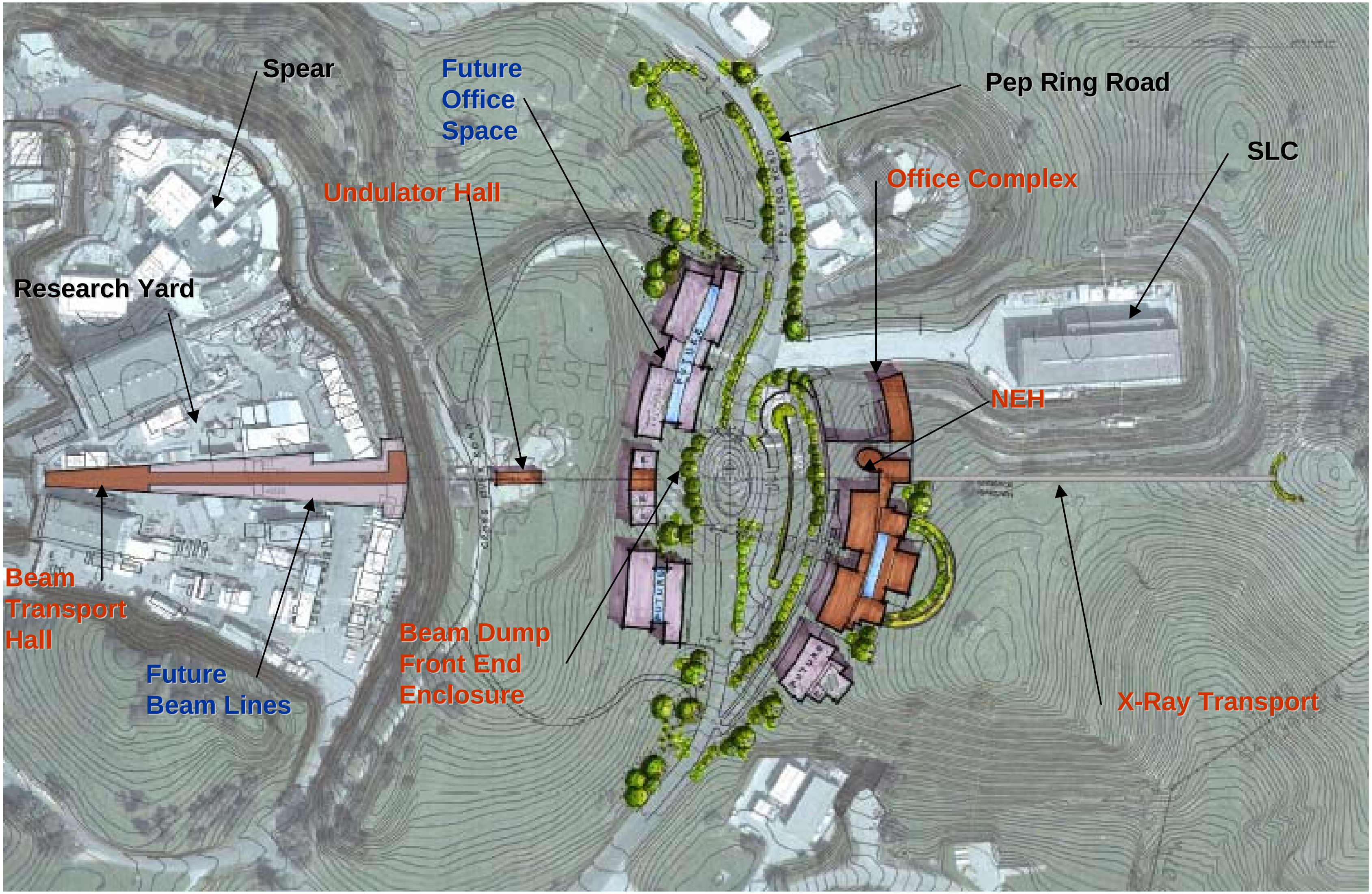
MMF Measurement Bench



Undulators being shimmed at the MMF

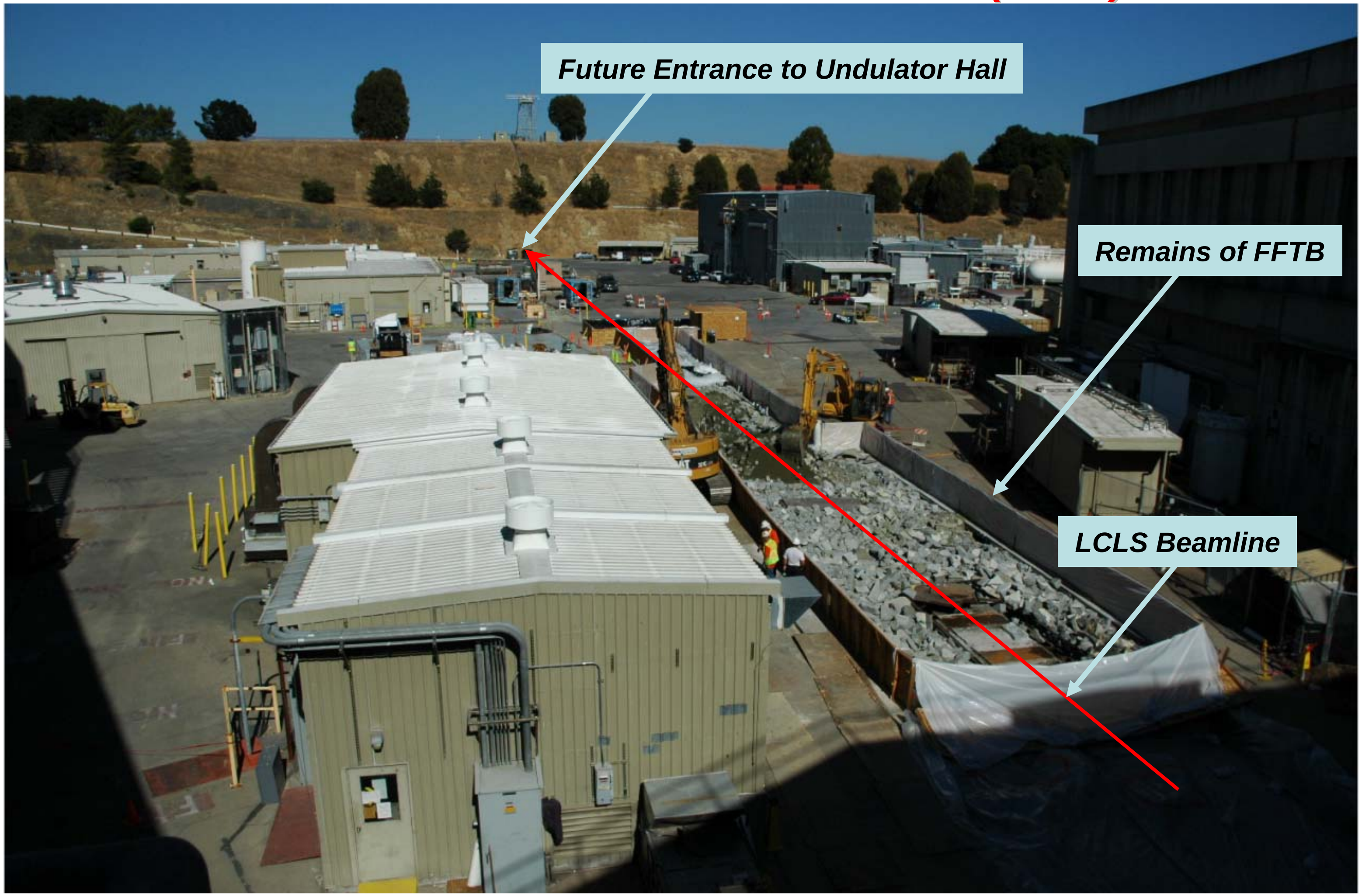
David H. Dowell
dowell@slac.stanford.edu

LCLS Site Plan



View of the Research Yard, Looking back toward the Linac

Construction has begun in the SLAC Research Yard with removal of the Final Focus Test Beam (FFTB)



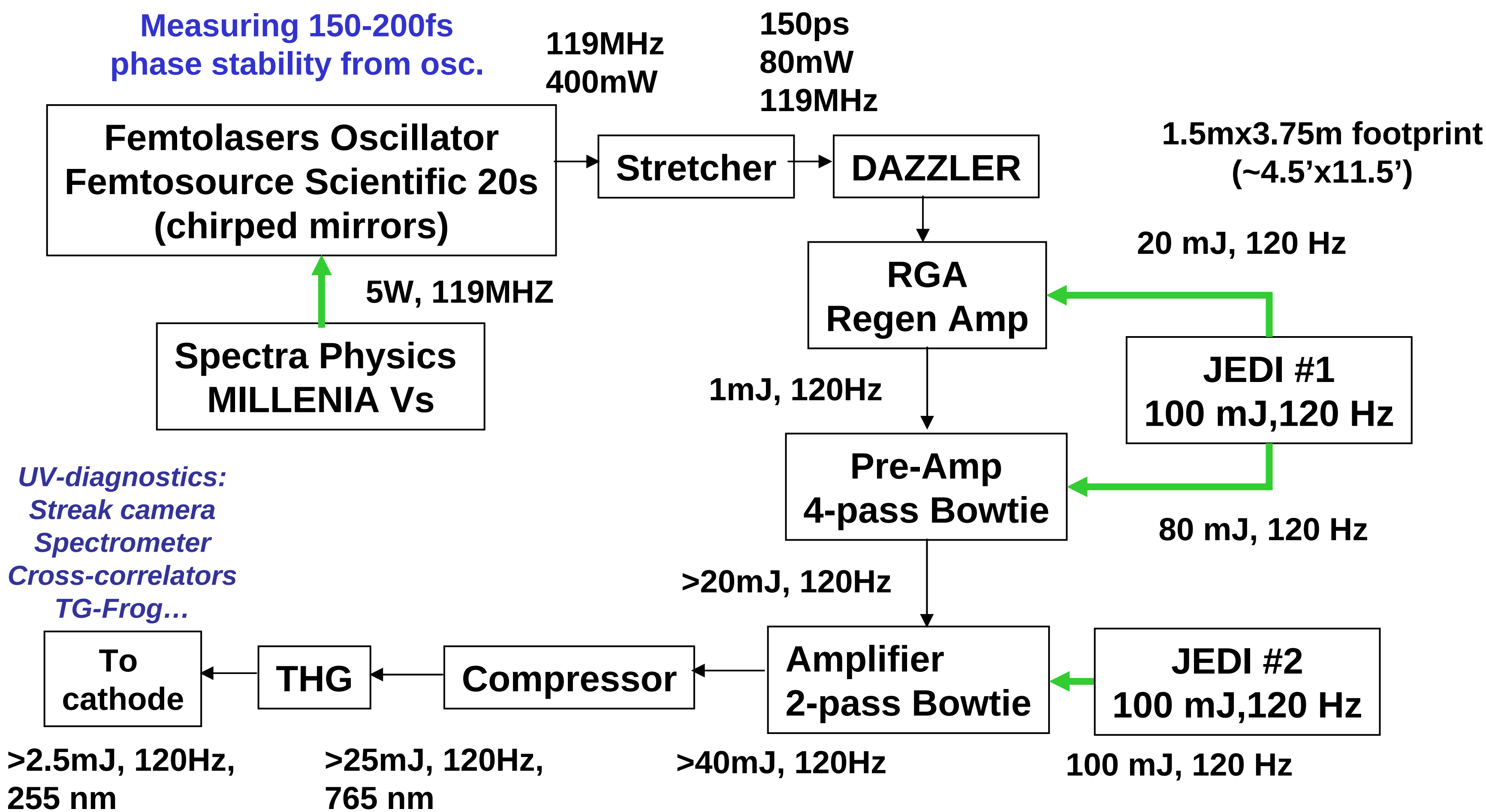
View east toward the experimental halls

Technical Challenges for Angstrom FEL's

- *Gun emittance*
  - *Cathode emittance, uniformity, and quantum efficiency*
  - *RF field quality*
  - *gun solenoid field uniformity and alignment*
- *Drive laser reliability, stability and 3D shaping (UV diagnostics)*
- *Emittance preservation*
  - *Optical aberrations and CSR*
  - *Wakefields*
- *Beam Instabilities (CSR, Longitudinal space charge)*
  - *Laser-Heater*
- *Bunch length diagnostics and control*
- *Alignment*
  - *gun to solenoid etc.*
  - *undulator*
- *Magnetic Measurements*
  - *Beamline components*
  - *New measurement facility for undulators*
- *RF power stability*
- *Vibrations*
- *Temperature stability and control*

David H. Dowell
dowell@slac.stanford.edu

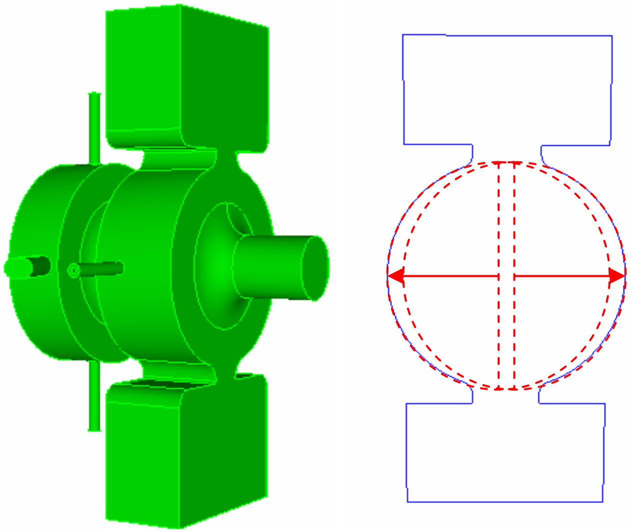
Thales Drive Laser System for LCLS



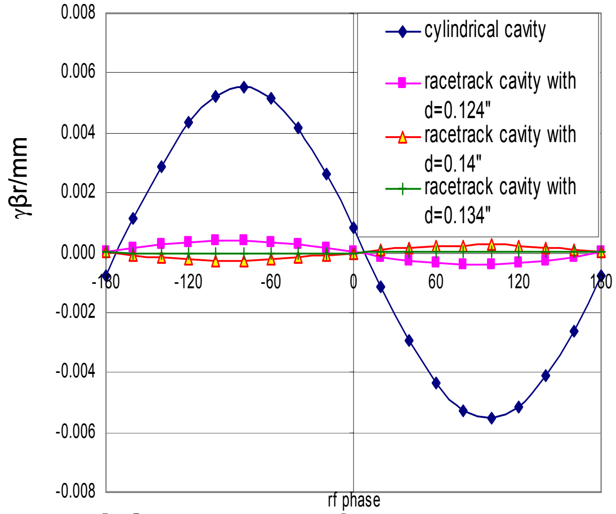
David H. Dowell
dowell@slac.stanford.edu

3D RF Design of Gun

- *Z-coupling:*
  - *reduces pulsed heating*
  - *increases vacuum pumping*
- *Racetrack to minimize quadrupole fields*
- *Deformation tuning to eliminate rf tuners*
- *Iris reshaped reducing field 10% below cathode*
- *Increase 0-pi mode separation to 15MHz*
- *All 3D features included in modeling:*
  - *laser port and pickup probes*
  - *3D fields used in Parmela simulation*



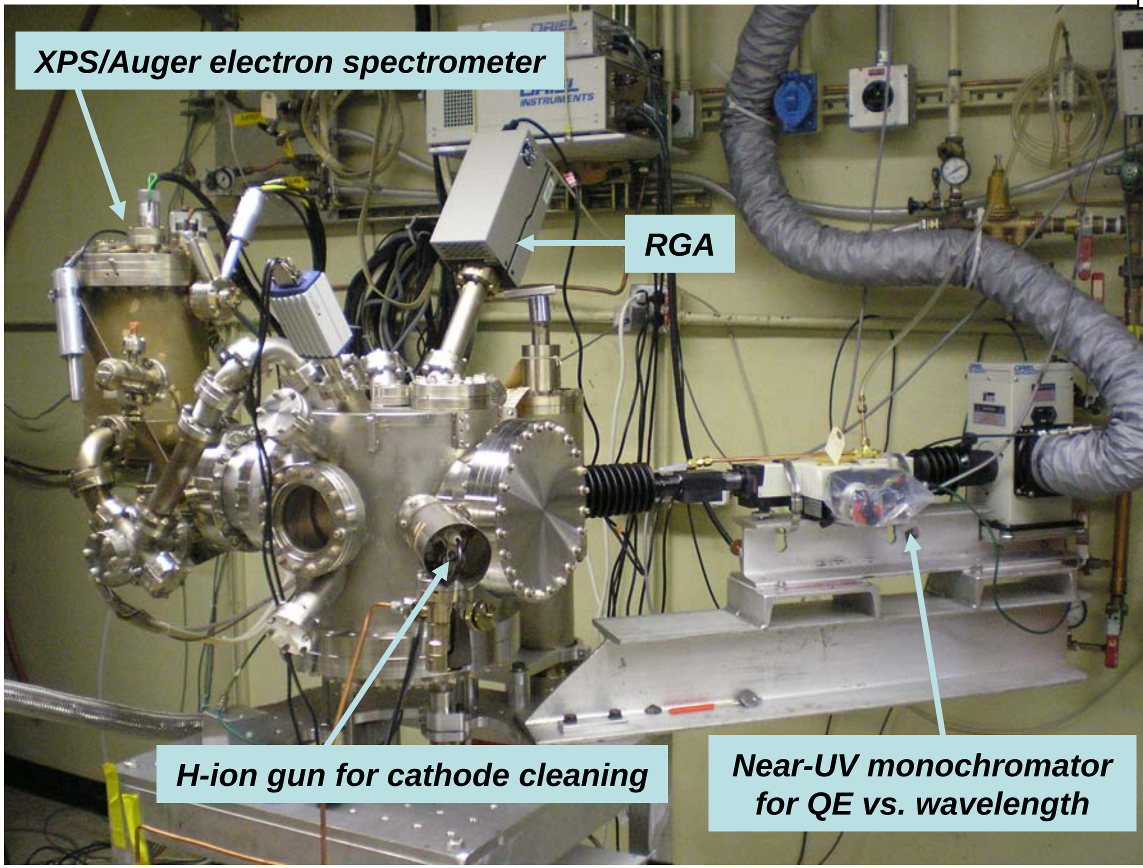
RF Parameters	
f0 (GHz)	2.855987
Q0	13960
β	2.1
Mode Sep. Δf (MHz)	15
E0:E1	0.999:1



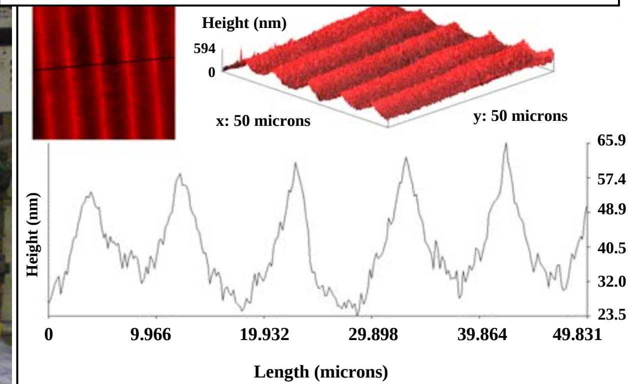
C. Limborg et al., "RF Design of the LCLS Gun", LCLS-TN-05-3
L. Xiao et al., "Dual feed rf gun design for the LCLS," Proc. 2005 Particle Acc. Conf.

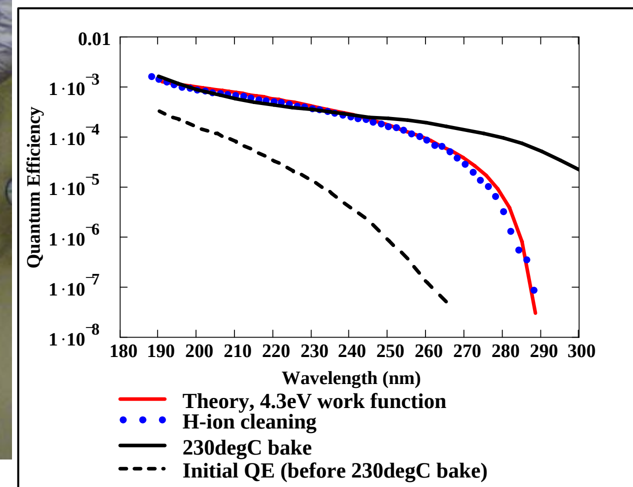
Compliments of Z. Li & L. Xiao

Cathode Qualification System (CQS)



AFM measurement of cathode surface

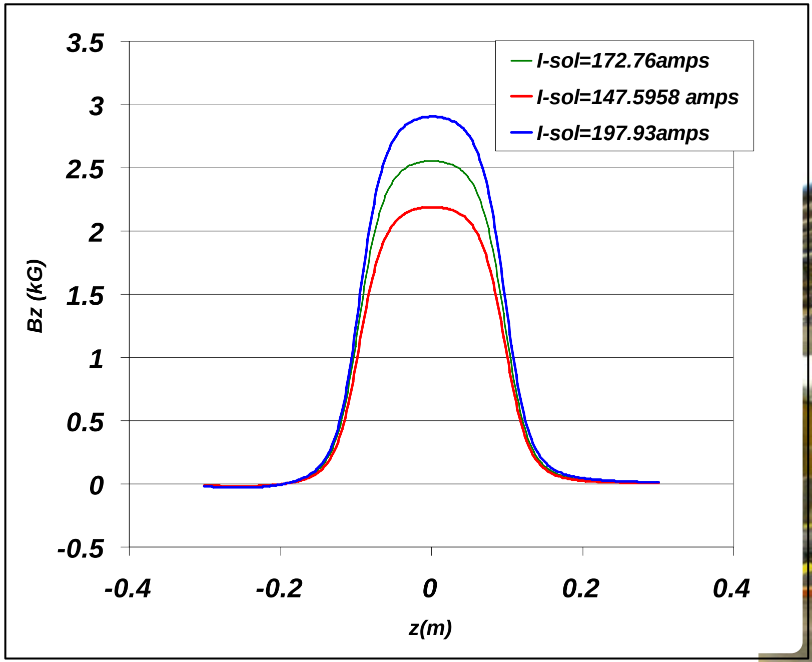




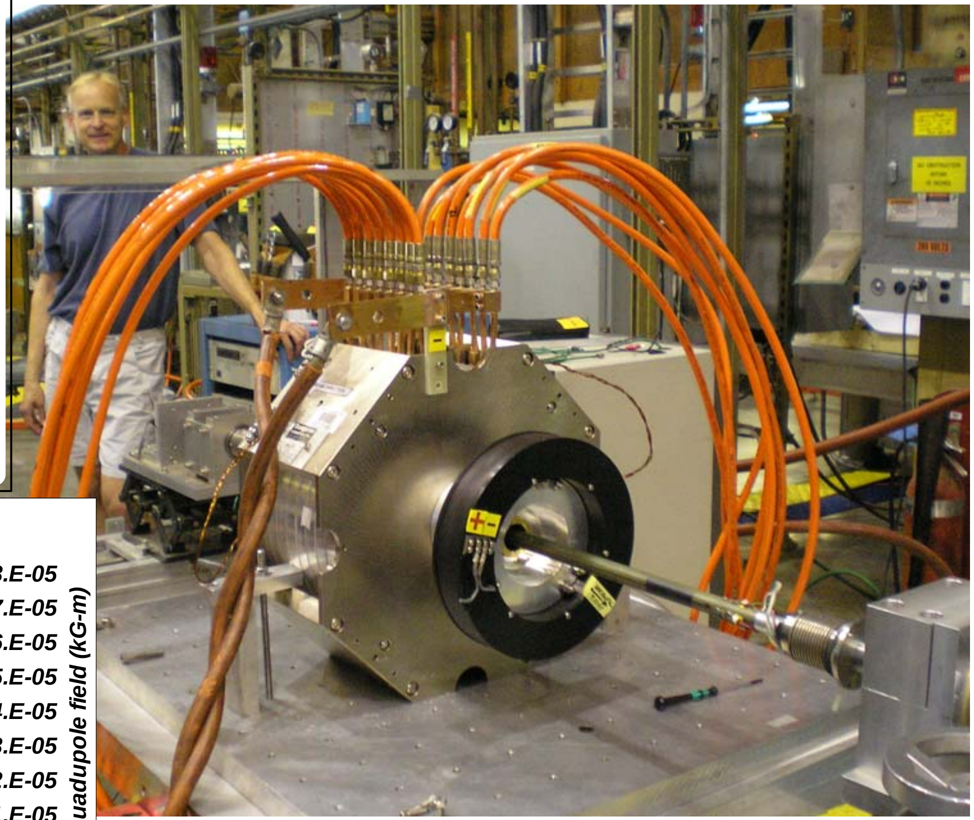
Compliments B. Kirby

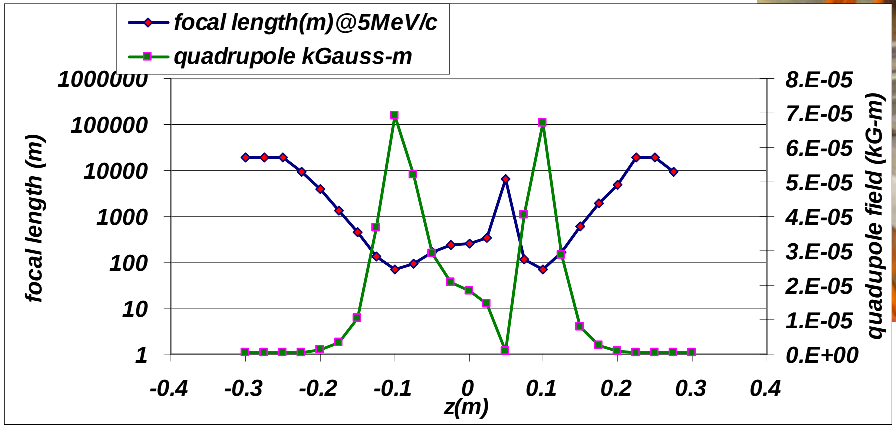
David H. Dowell
dowell@slac.stanford.edu

Magnetic Measurements and Calibrations are being performed on all beamline magnets



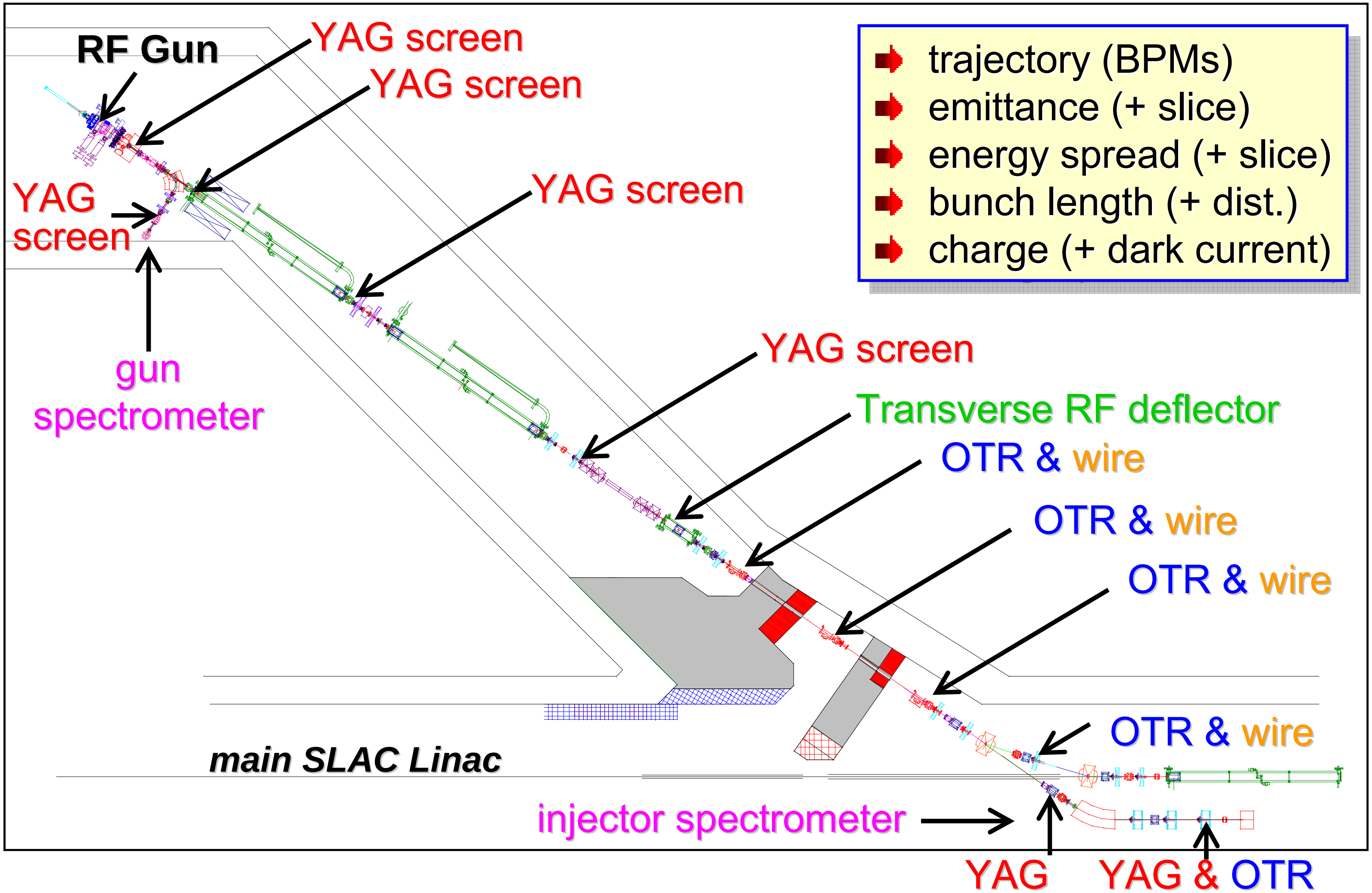
Gun Solenoid on Magnetic Meas. Test Stand





David H. Dowell
dowell@slac.stanford.edu

Injector Diagnostics Are Essential



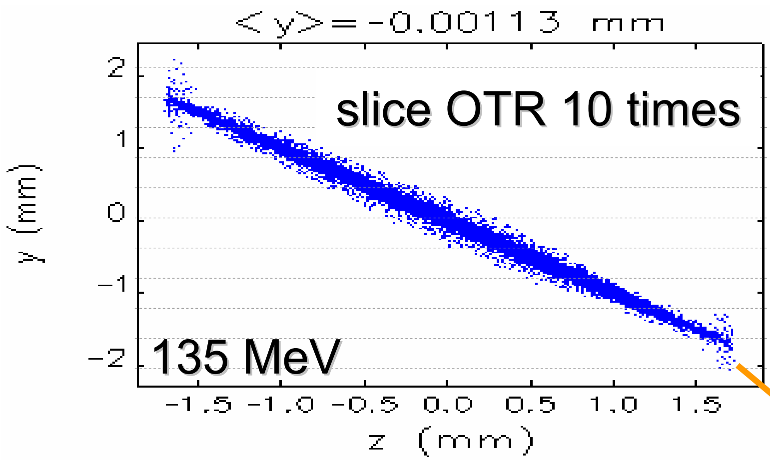
- trajectory (BPMs)
- emittance (+ slice)
- energy spread (+ slice)
- bunch length (+ dist.)
- charge (+ dark current)

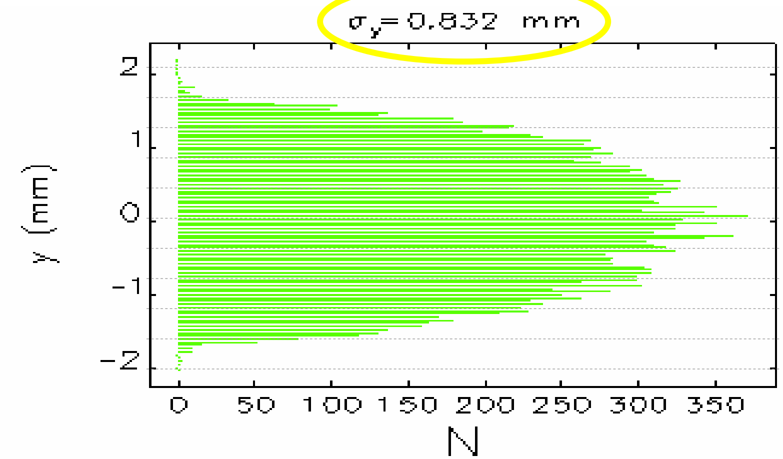
David H. Dowell
dowell@slac.stanford.edu

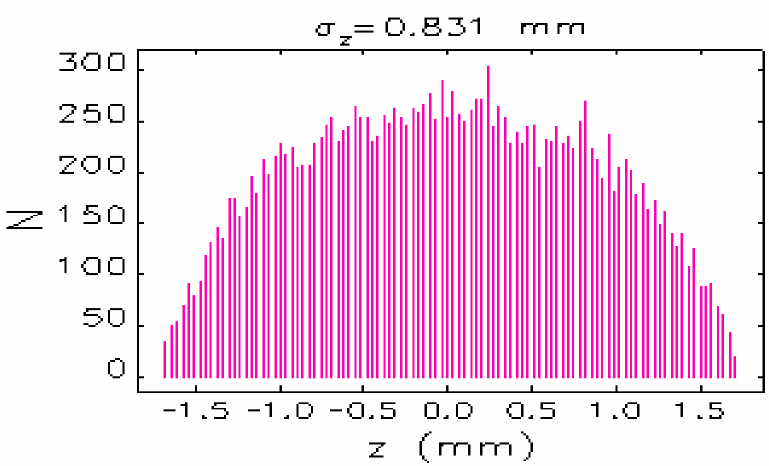
Slice-Emittance Measurement Simulation

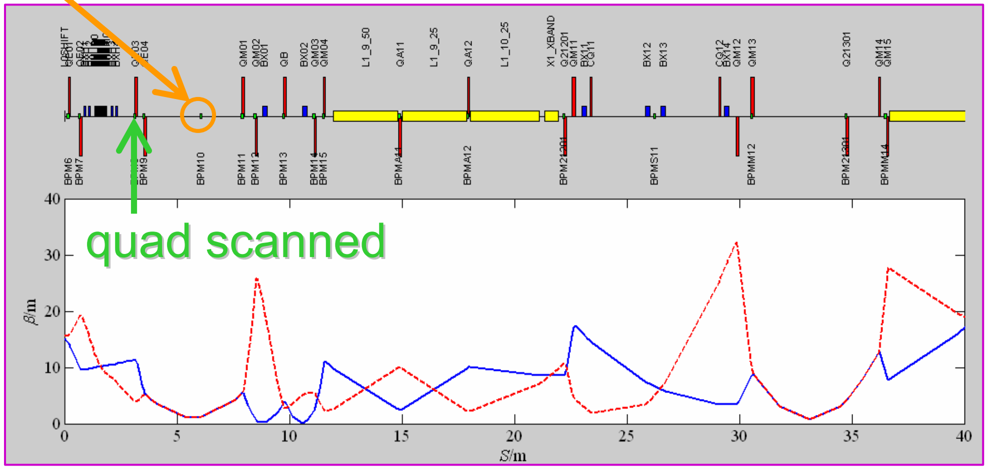
Transverse RF-deflector at 1 MV

$\sigma_y \approx$ **bunch length**







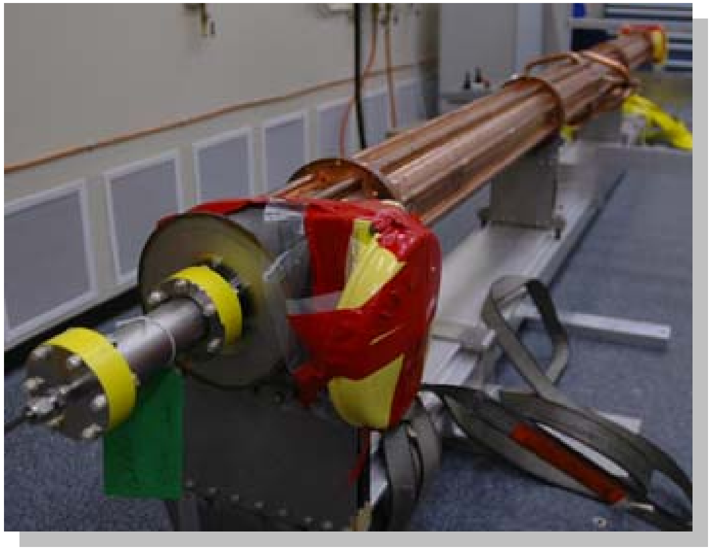


Compliments P. Emma

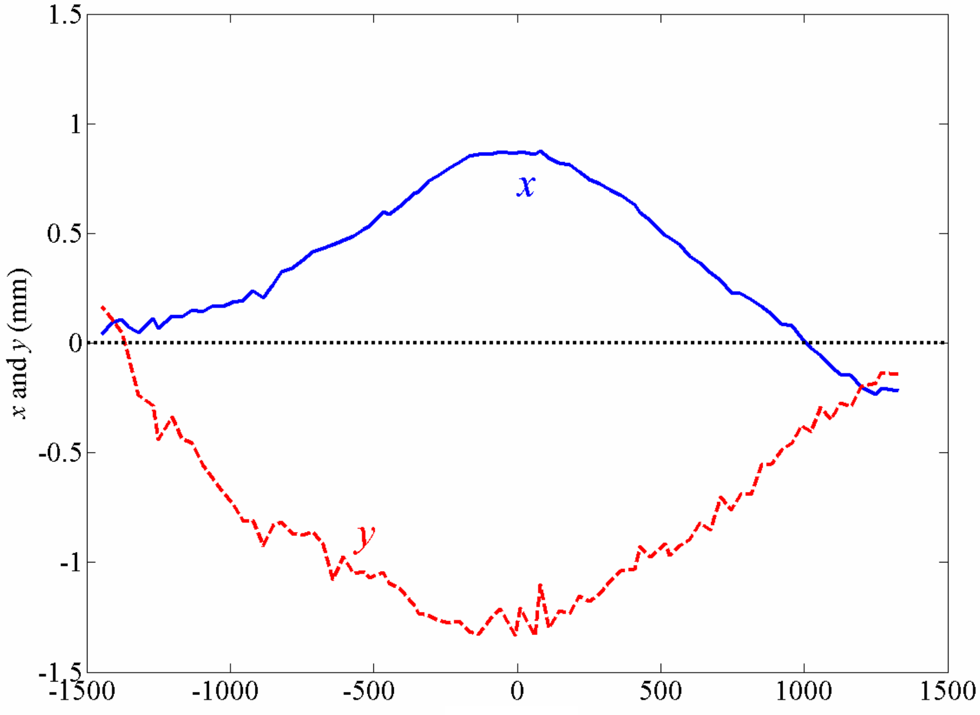
Alignment and Measurement of Everything is Important: Straightness of Injector Linac Section

Coordinate measurement machine measurement of s-band linac showed a significant bow

Injector S-band Section on CMM



Nearly straightened already (Aug. 21, '06)

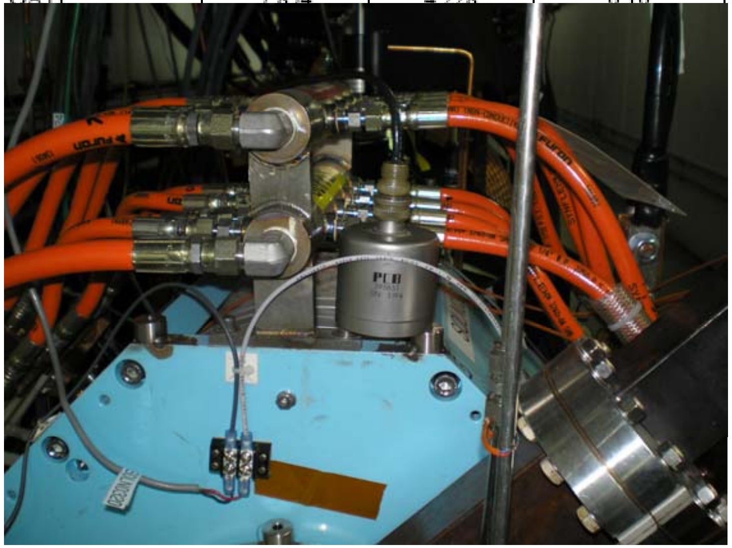


David H. Dowell
dowell@slac.stanford.edu

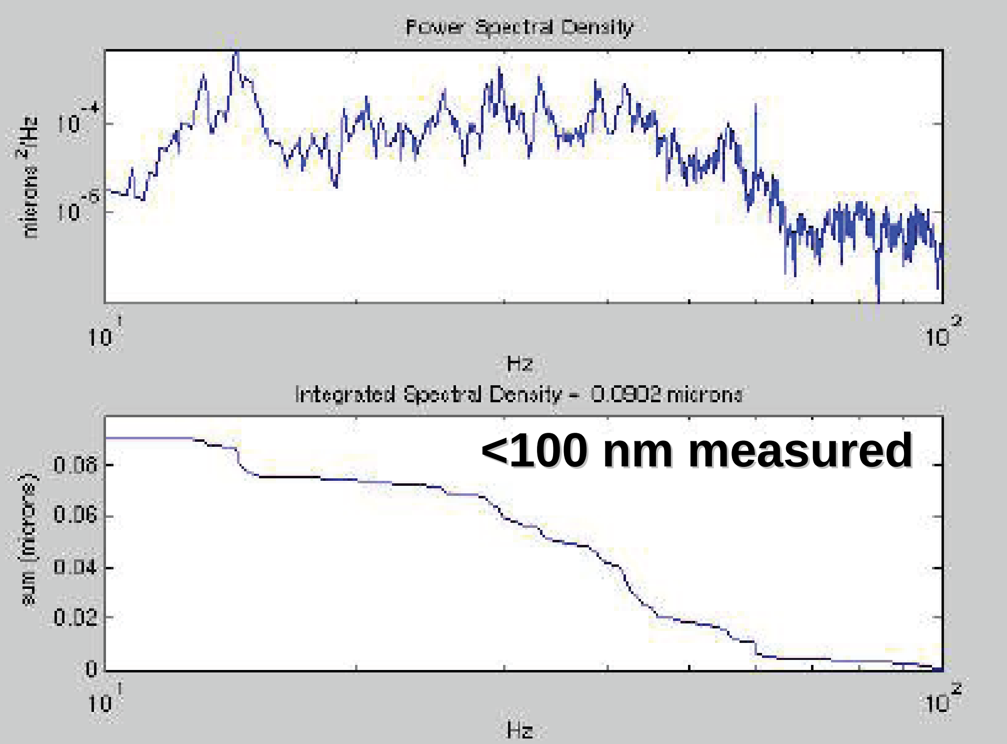
Vibration Tolerances have been Determined for all Beamline Components, Especially Solenoids & Quadrupoles

Magnet Name	Δx_i, sensitivity [μm]	Δy_i, sensitivity [μm]	σ_i, rms tolerance [μm]
S1	1.2	1.2	0.10
S2	2.615	2.850	0.50
QA01	2.615	2.850	0.10
QA02	1.864	3.338	0.10
QE01	25.023	21.28	0.50
QE02	12.427	9.899	0.50
QE03	2.493	4.259	0.10
QE04	3.918	4.203	0.10
QM01	1.615	1.652	0.10
QM02	6.088	1.007	0.10
QM04	1.244	3.158	0.10
QA11	7.854	4.228	0.10

LCLS Physics Req. Doc. 1.1-008, P. Emma



Vibration measurements performed on similar gun and solenoid for E-163 Experiment

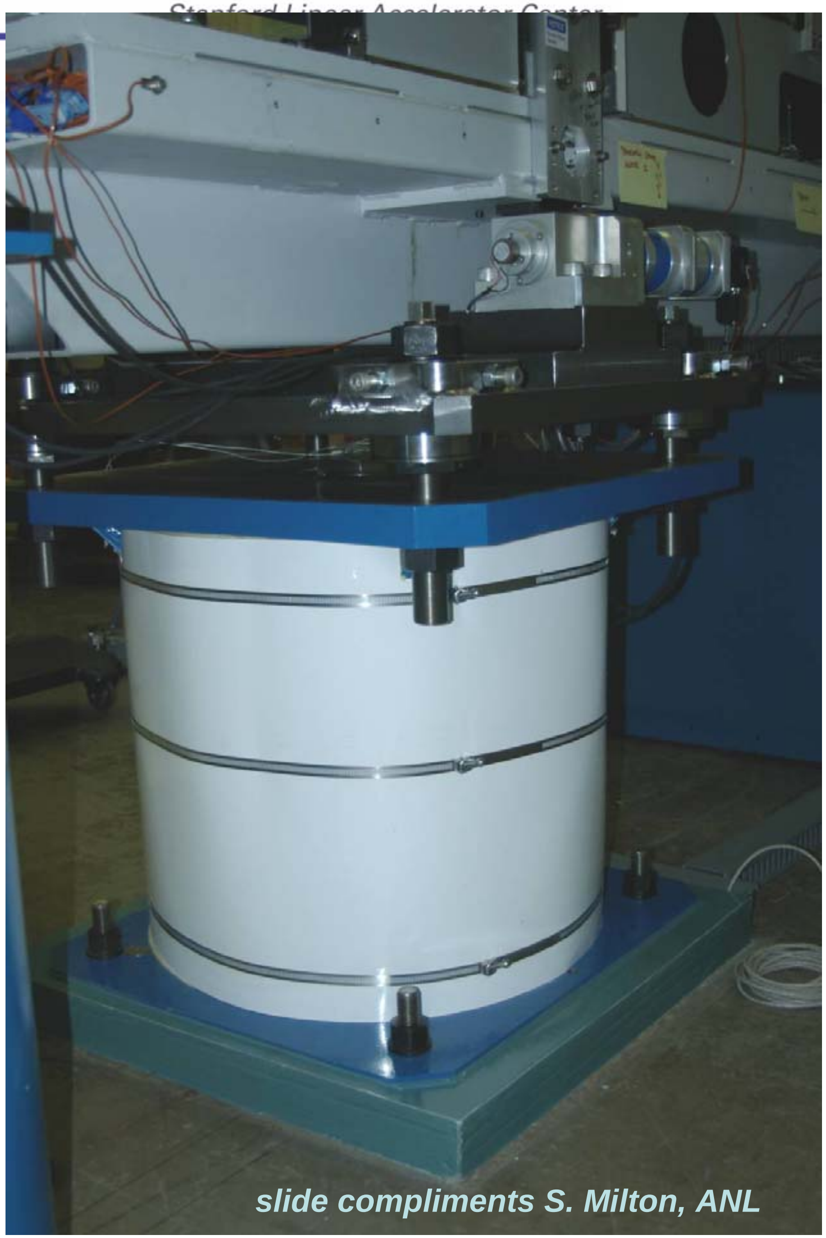


Measurement compliments of J. Turner

David H. Dowell
dowell@slac.stanford.edu

Undulator Support System

- Fixed Pedestal
  - *Designed to be very stable in temperature due to concerns of thermal expansion shifting the quadrupoles*
    - *Insulated*
    - *Filled with sand*
    - *Note: Hall temperature stabilized to +/- 1 deg F*

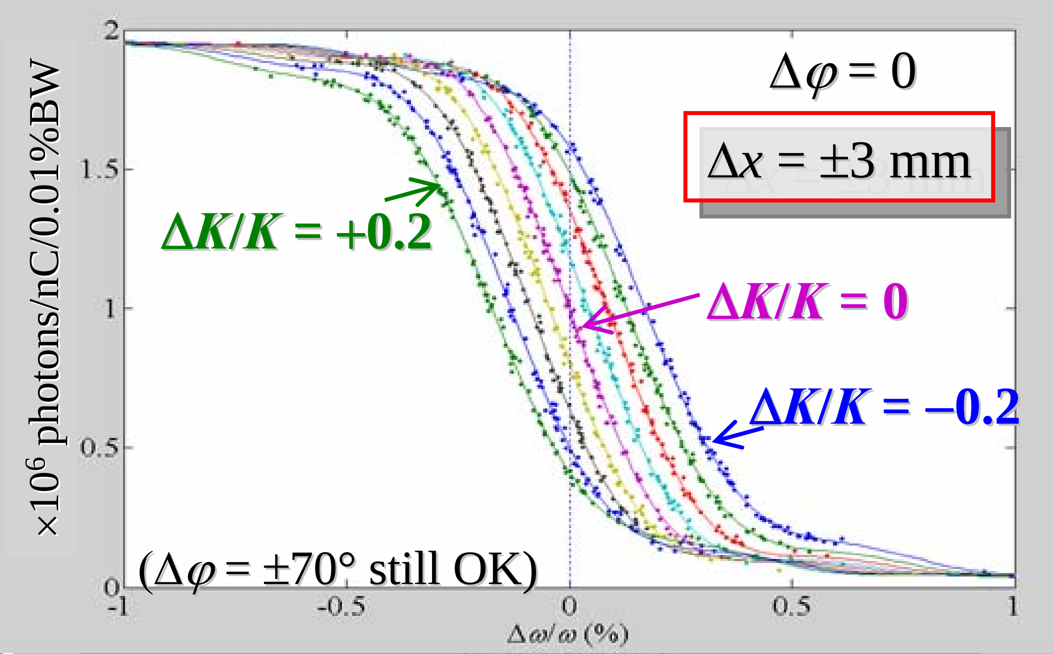


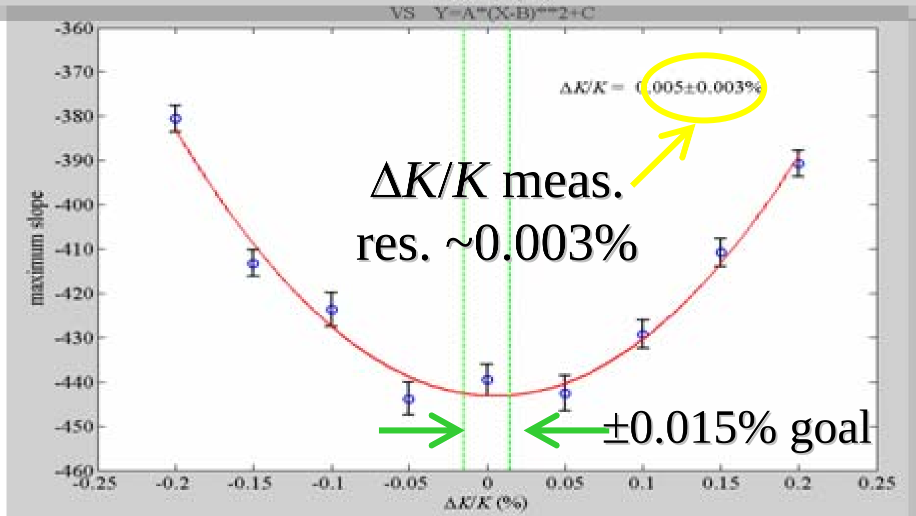
slide compliments S. Milton, ANL

David H. Dowell
dowell@slac.stanford.edu
Stanford Linear Accelerator Center

In-Situ Measurement of Undulator K using Angle-Integrated Spontaneous Spectra for 2 Undulators

- Insert 2 ~adjacent undulators.
- Measure e^- energy per pulse.
- $(\Delta\omega/\omega)_{rms} \approx 0.2\%$, measured to 0.006% resolution.
- Use Si crystal on 111-axis to meas. angle-integrated high-energy spectrum edge.
- Scan undulator x-position ($\Delta K/K = -0.2$ to $+0.2\%$).

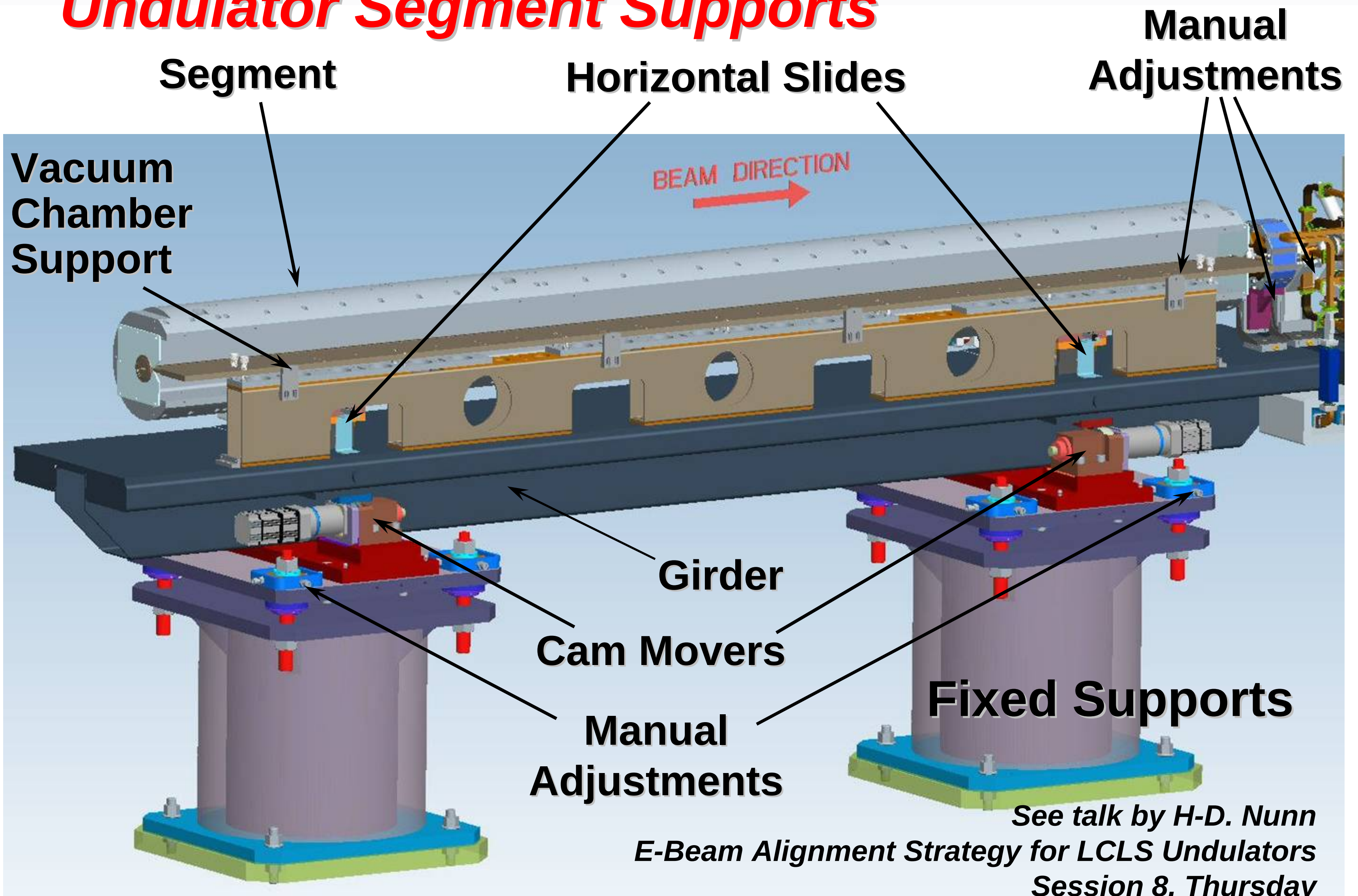




See talk by J. Welch, Session 8, Thursday

David H. Dowell
dowell@slac.stanford.edu

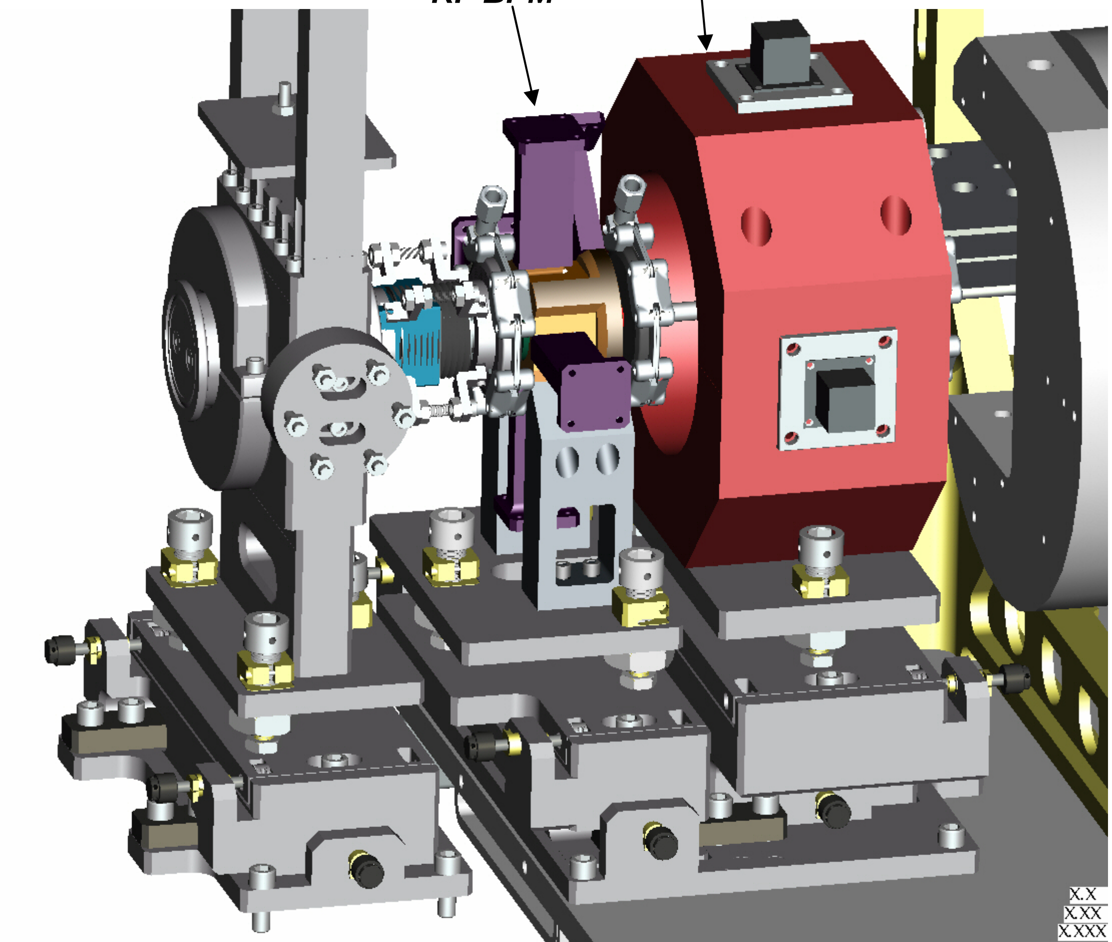
Undulator Segment Supports



See talk by H-D. Nunn
E-Beam Alignment Strategy for LCLS Undulators
Session 8, Thursday

David H. Dowell
dowell@slac.stanford.edu

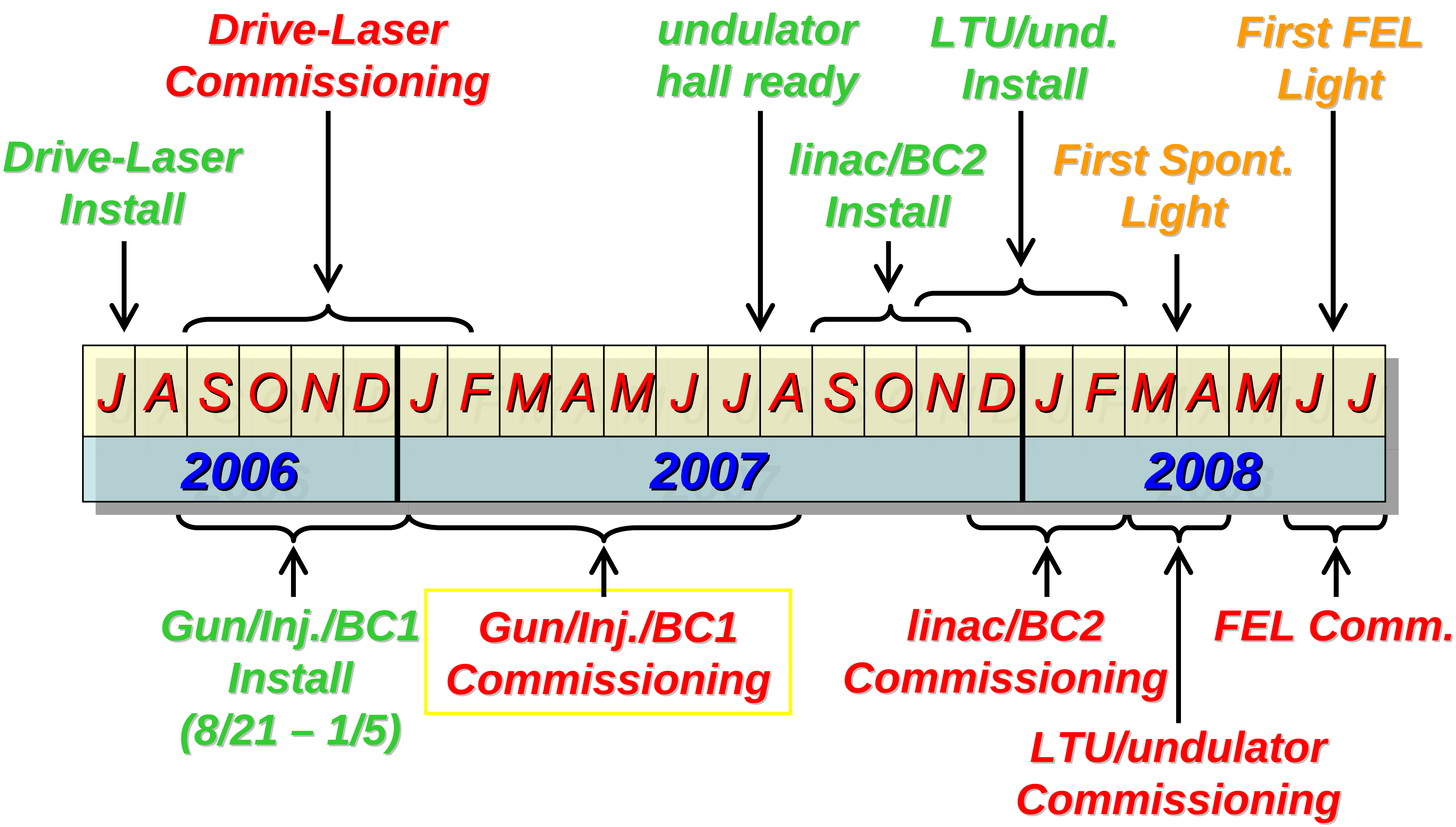
Design of Region Between the Undulators



Undulator RF Beam Position Monitor

David H. Dowell
dowell@slac.stanford.edu

LCLS Installation and Commissioning Time-Line



David H. Dowell
dowell@slac.stanford.edu

Summary

- ***LCLS construction has begun:***
  - ***Laser building at Sector 20 finished***
  - ***Drive laser delivered, installed & operating***
  - ***RF gun fabricated and high-power testing in Sept.***
  - ***Beamline through BC1 installation begun***
  - ***Final Focus Test Beam (FFTB) removed for LCLS construction***
  - ***Undulators arriving from ANL and being magnetically shimmed in new Magnetic Measurement Facility (MMF)***
- ***LCLS design addresses many of the varied technical challenges of Angstrom FELs***
- ***Commissioning of Injector through BC1 to begin in early 2007***
- ***On schedule for first light in 2008 and beam for users in 2009.***

David H. Dowell
dowell@slac.stanford.edu