LCLS Commissioning Plans

(Dec. 1, 2006 through Mar. 30, 2009,…and beyond)

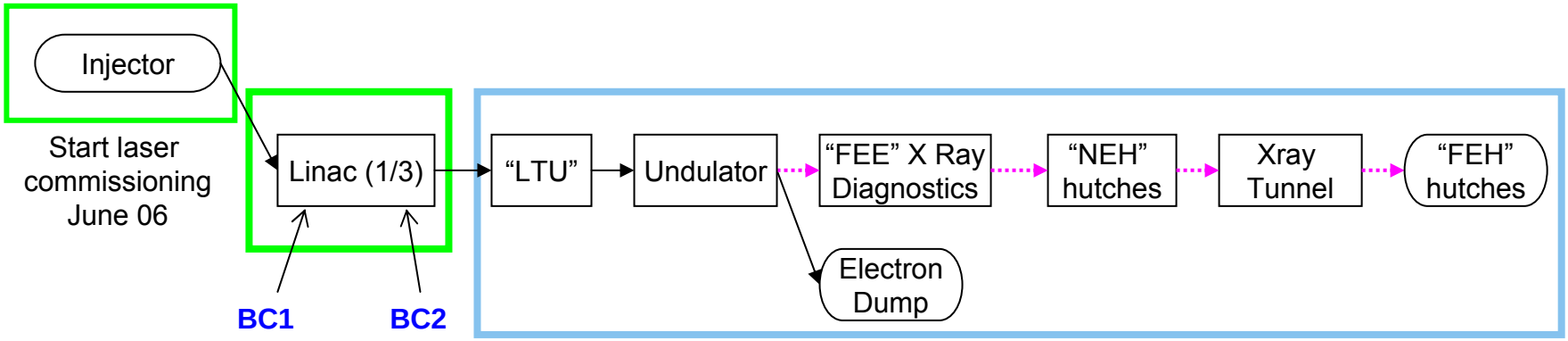
J. Welch

ICFA FLS 2006

Acknowledgements

- J. Arthur, R. Bionta, E. Bong, Y. Ding, D. Dowell, P. Emma, Z. Huang, P. Krejcik, K. LeCocq, C. Limborg, S. Milton, S. Moeller, H-D Nuhn, S. Reiche, R. Ruland, P. Stefan, H. Tompkins, J. Wu, and many others.

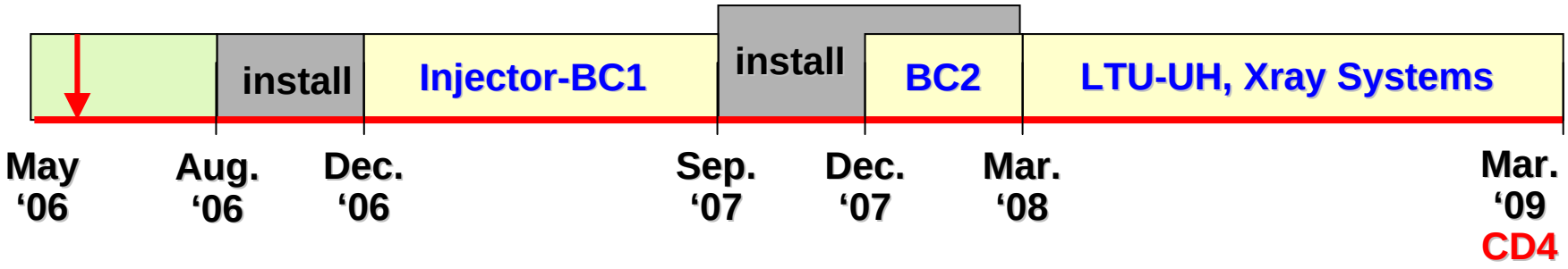
Overview of Beamlines and Timeline



Existing and refurbished housing

New housing construction. Completion by ~ Oct. 07

LTU: Linac to Undulator
FEE: Front End Enclosure
NEH: Near Experimental Hall
FEH: Far Experimental Hall
BC1(2): Bunch compressors



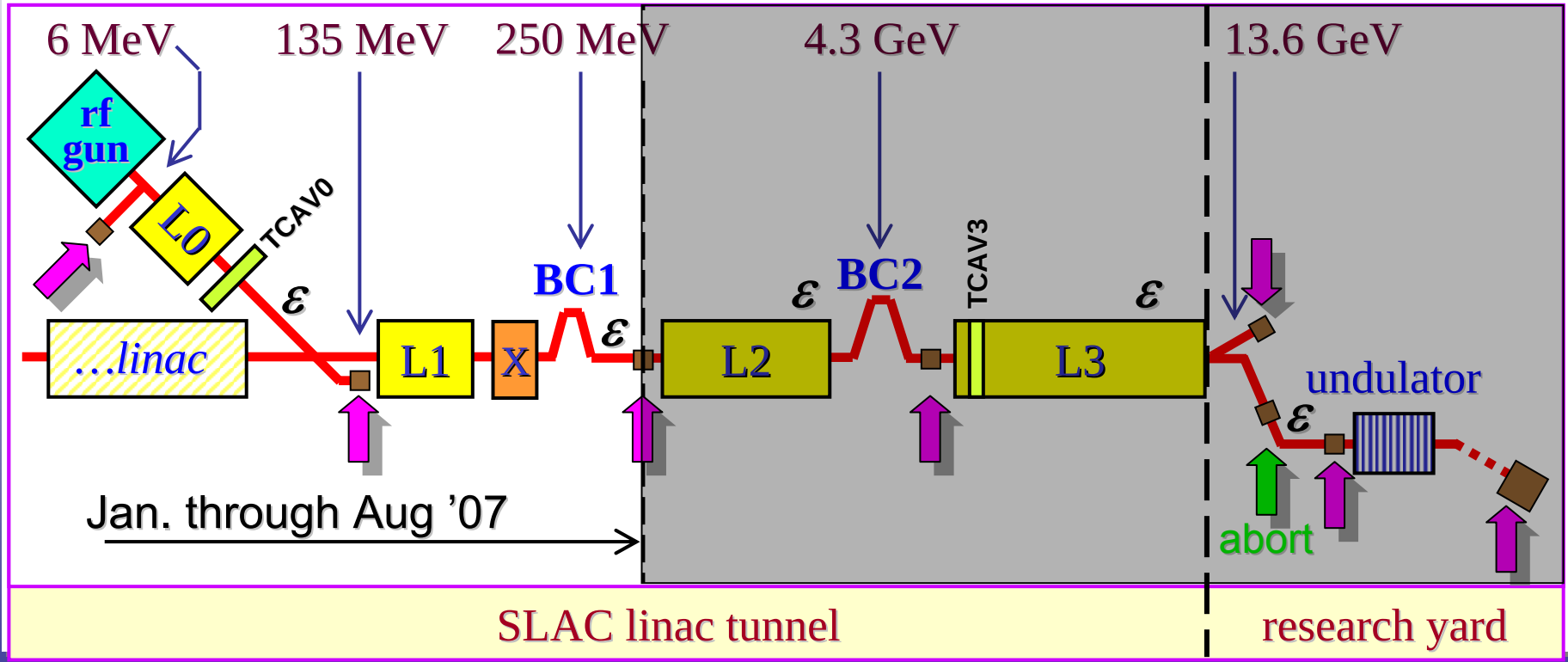
James Welch
Welch@SLAC.Stanford.edu

Key Near-Term Dates

Laser Delivered	June 06
Laser Installed	Aug 06
Linac Shutdown Start	Aug 06
Gun Tested	Sept 06
Gun Installed	Nov 06

Commissioning – Tune-up 'Stoppers'

Full set of beam diagnostics at each tune-up point

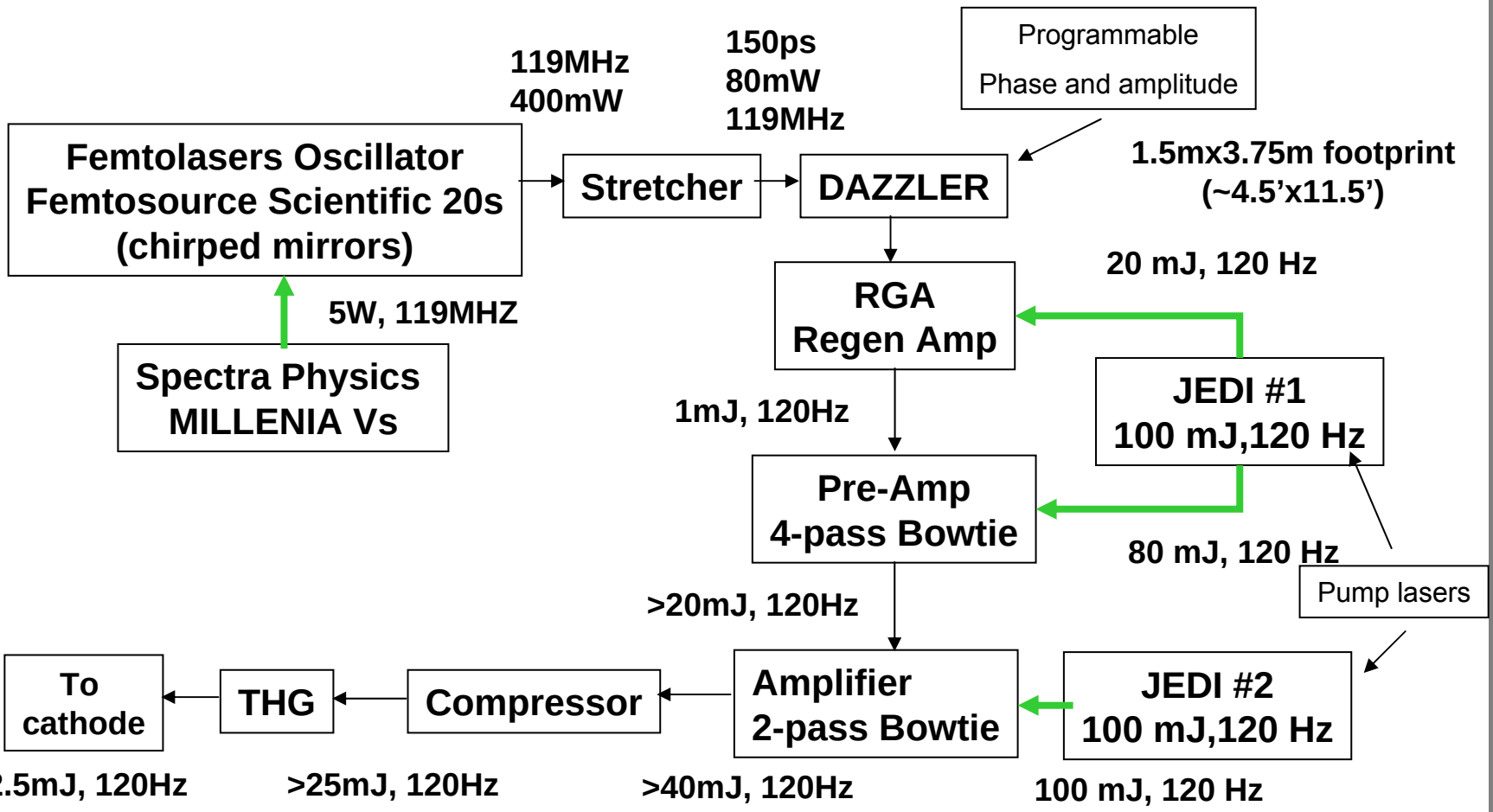


Injector

- Drive Laser and delivery optics
- Gun
- Injector accelector
  - Linac accelerating modules
  - Transverse rf deflector
  - BC1
  - X band section
  - Straight ahead beam diagnostics

James Welch
Welch@SLAC.Stanford.edu

Thales Drive Laser System



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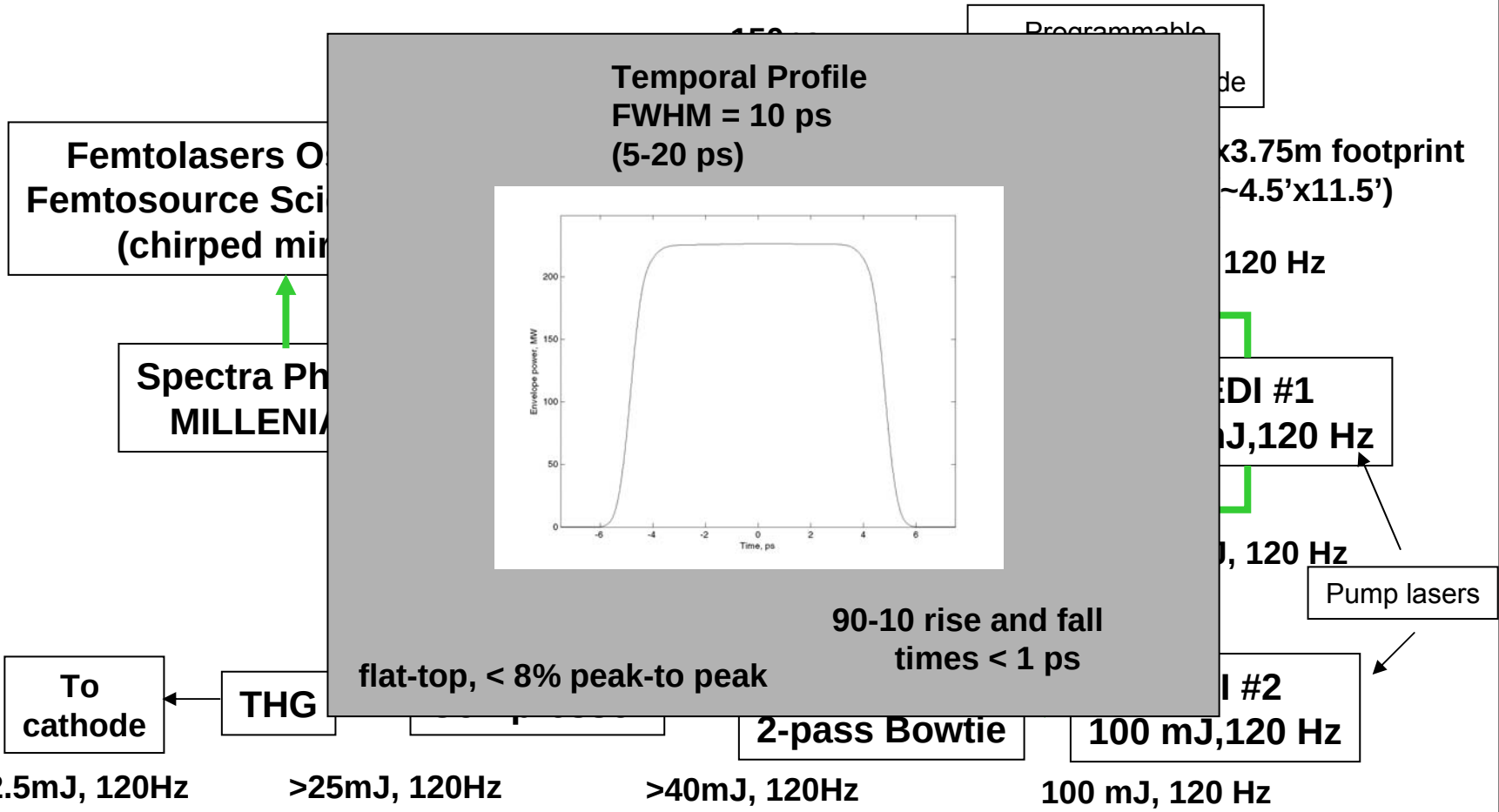
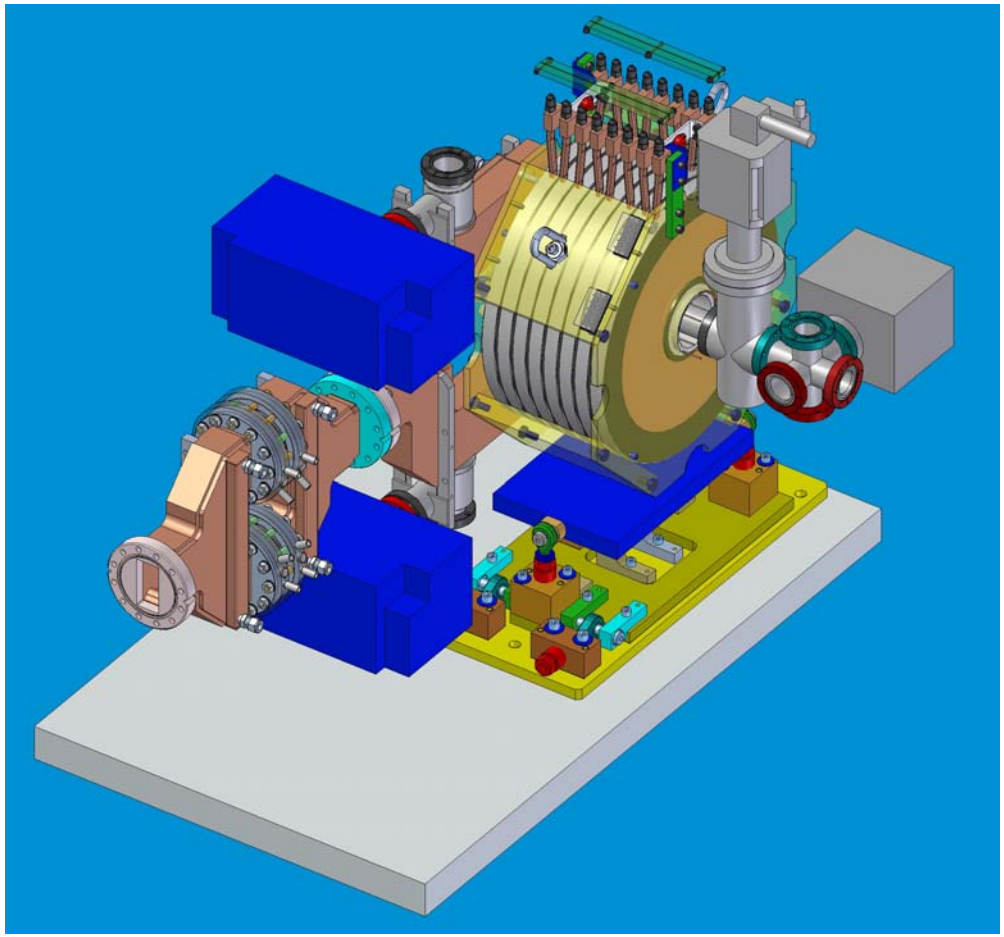


Injector - Gun

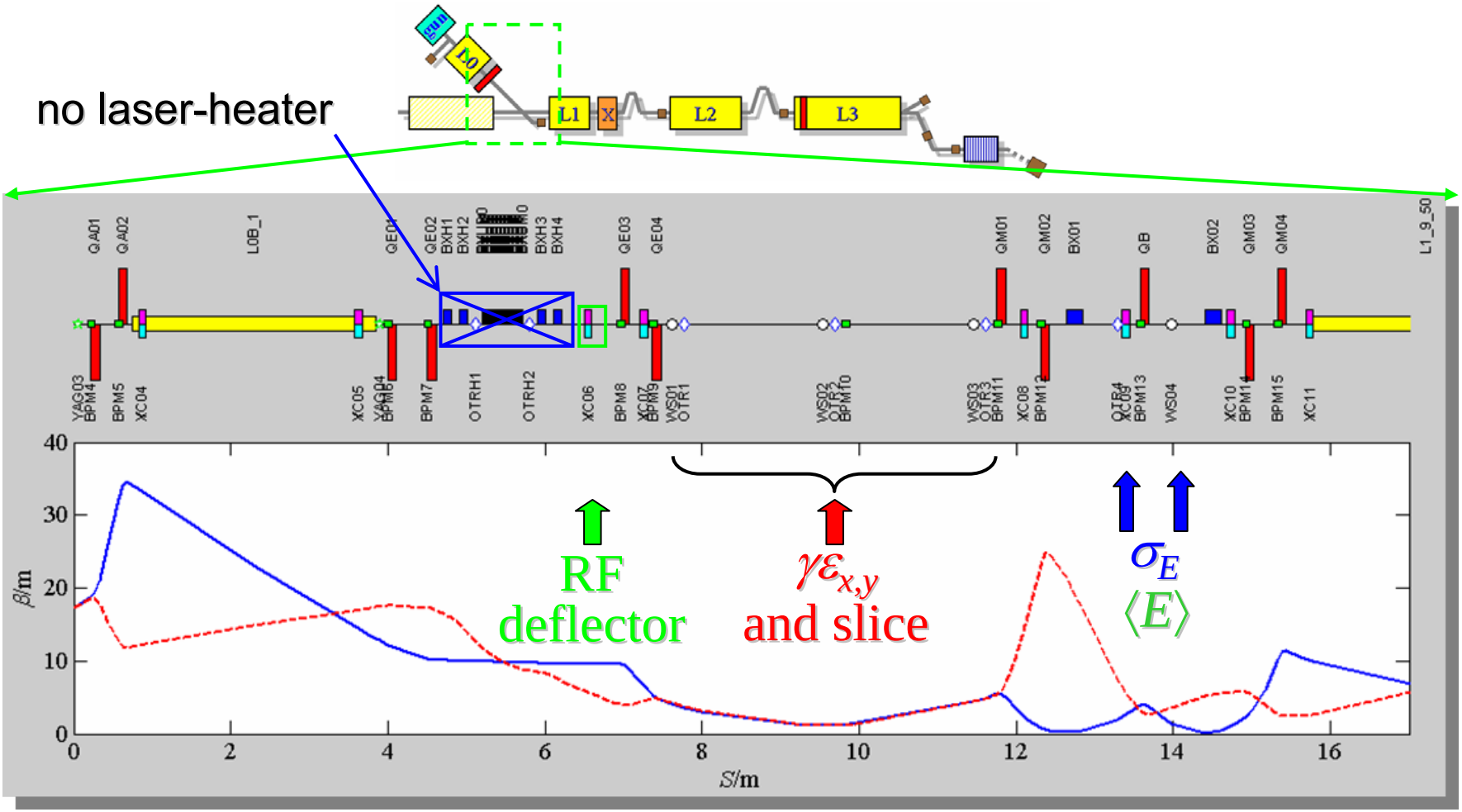
- Installation in Nov., after hot testing
- Commissioning starts with rf processing



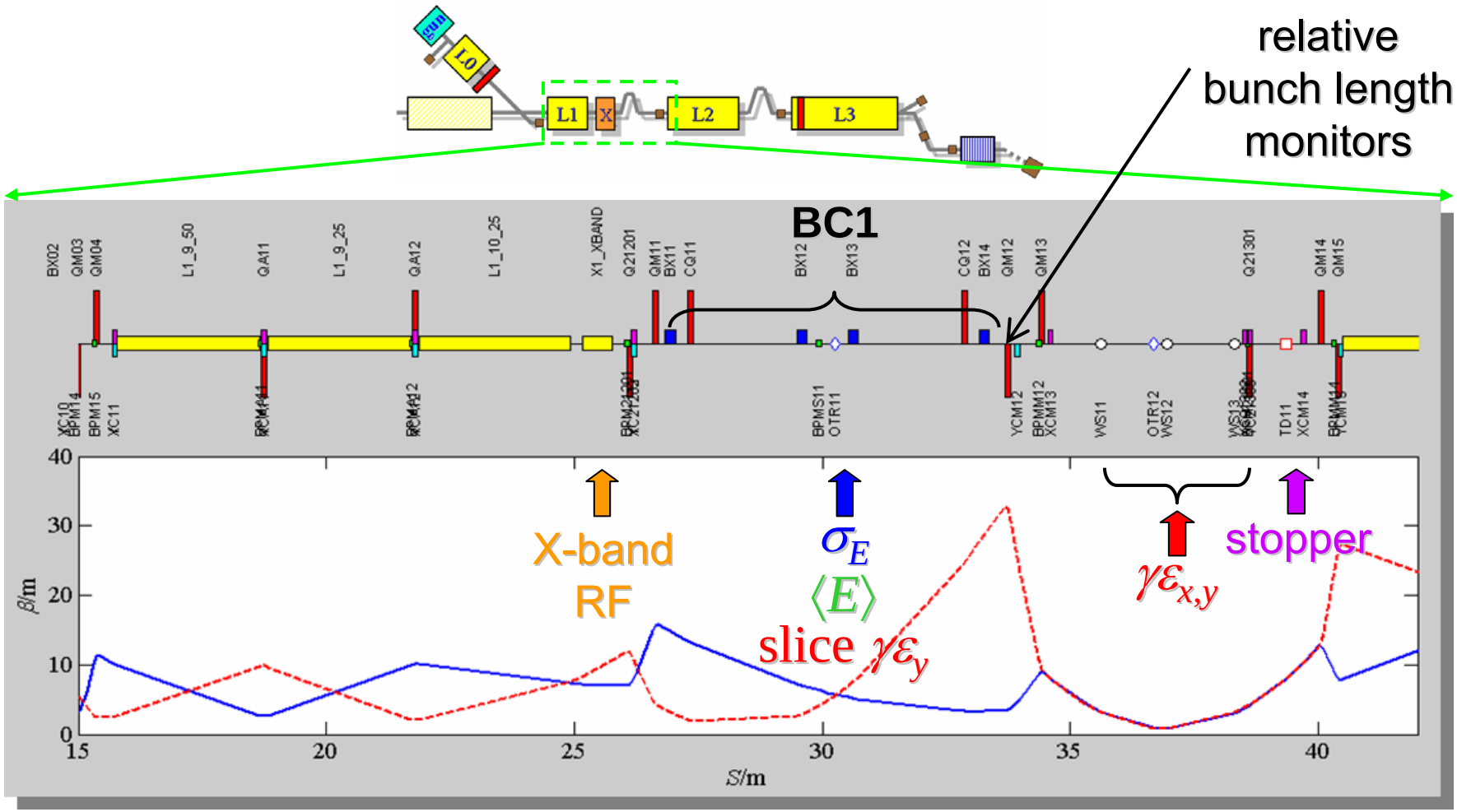
James Welch
Welch@SLAC.Stanford.edu

Injector Through BC1 Commissioning

Jan 07 - Aug 07



Injector Through BC1 Commissioning (2)

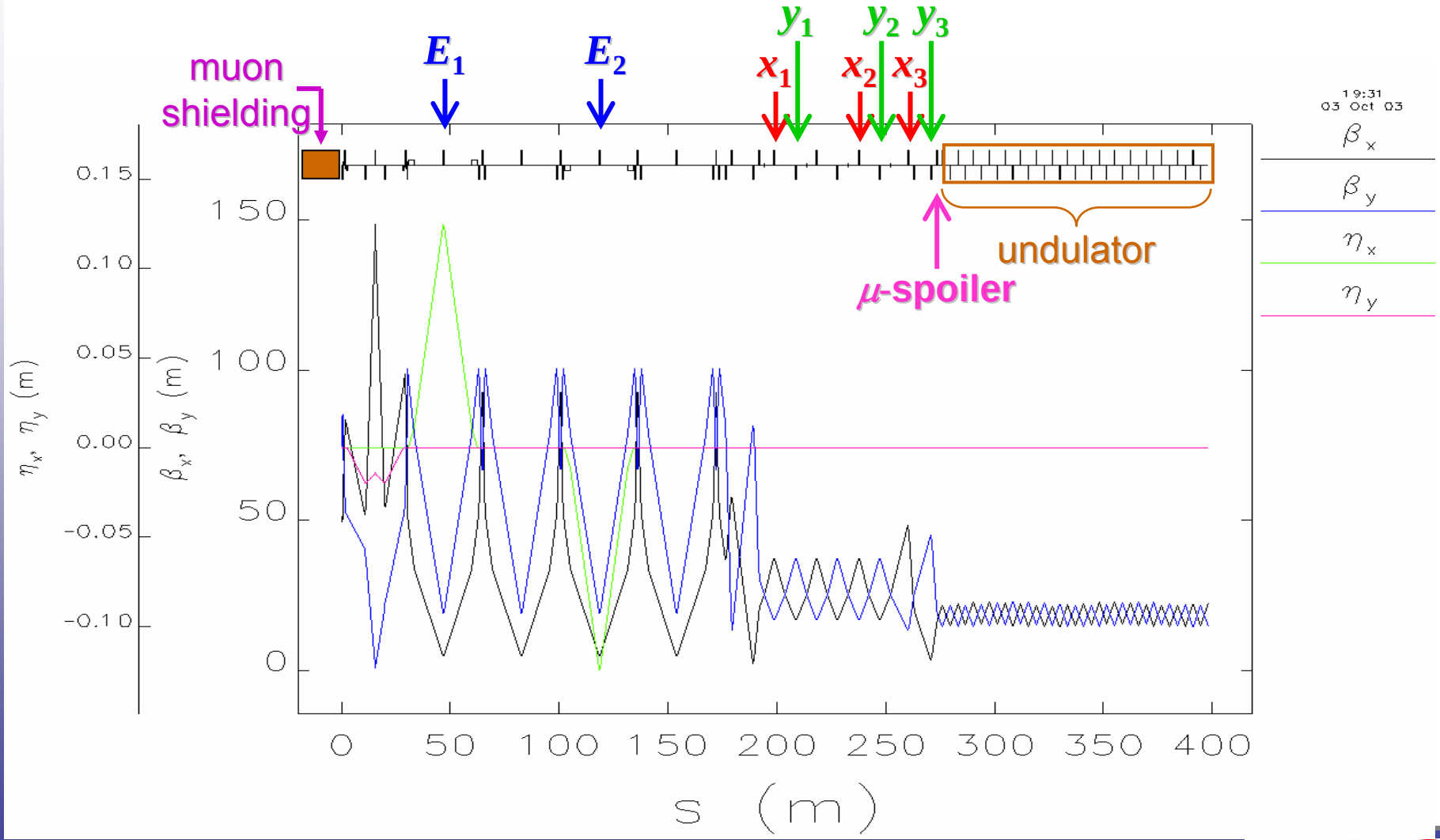


BC2, LTU, Undulator and Beam Dump

- BC2 is commissioned simultaneously with installation of undulator and LTU beamlines.
- **LTU include energy and 4-D transverse collimation to clean up beam before Undulator.**
- Full energy and emittance measurement in LTU just before undulator.

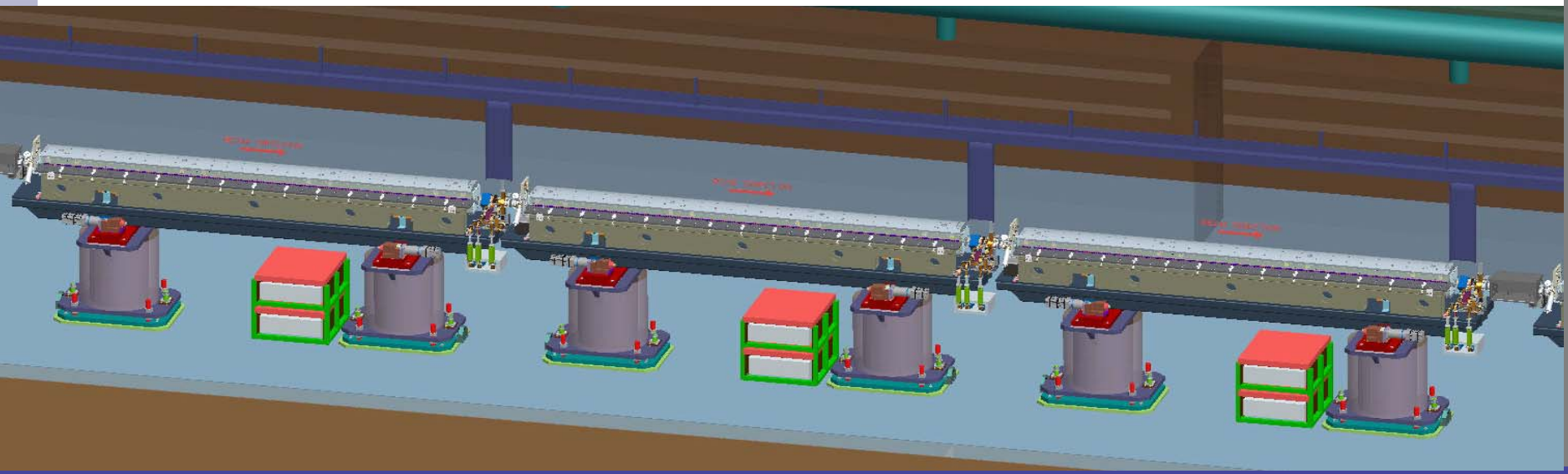
James Welch
Welch@SLAC.Stanford.edu

Collimation in Linac-to-Undulator (LTU)



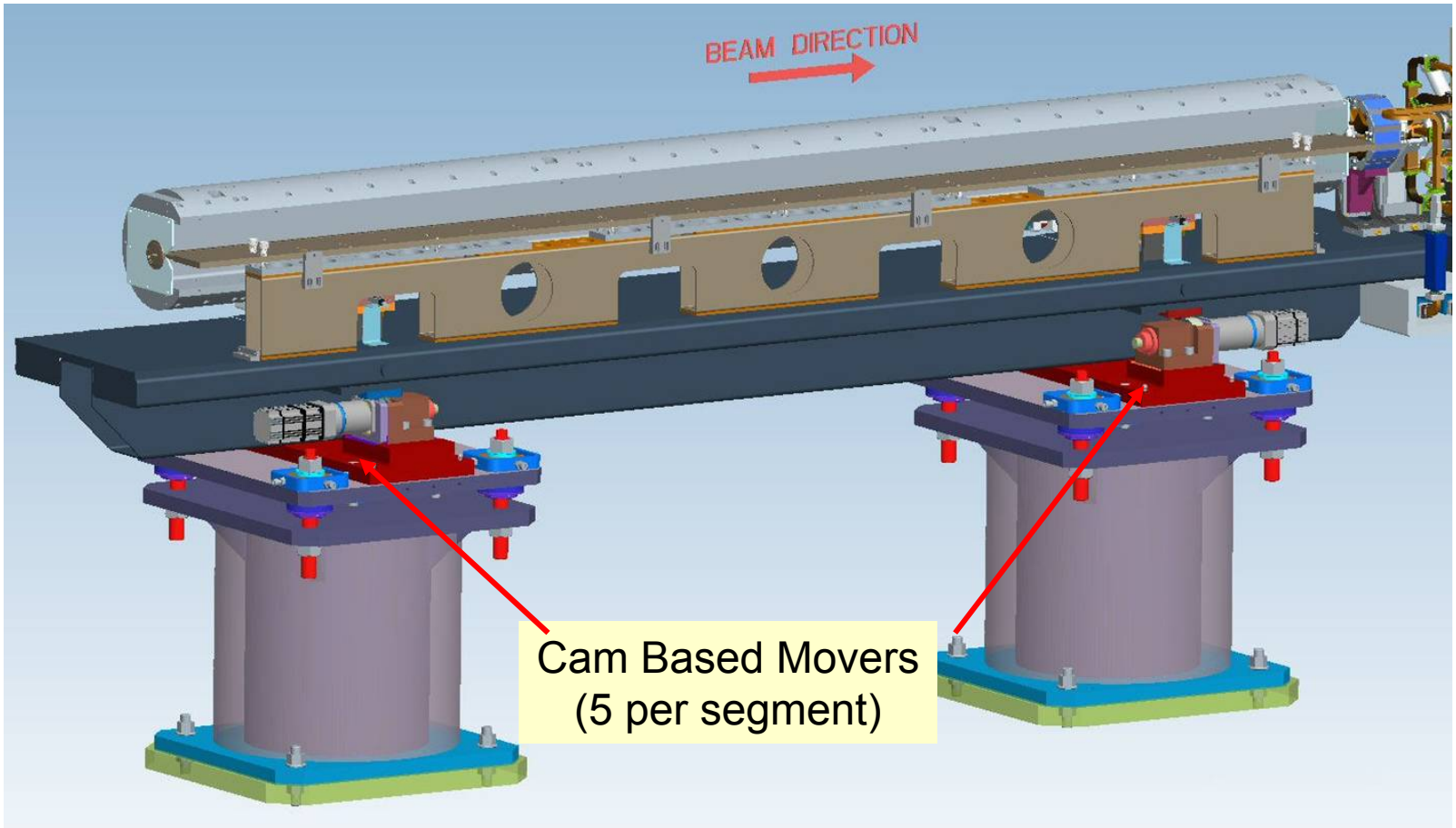
Undulator Commissioning

- Pre-Beam Commissioning
  - Control System
  - **Component Position Monitoring System**
  - Vacuum System
  - Magnet System
  - Beam Finder Wire System
  - **Motion Control System**
  - Temperature Monitoring System
  - System level software

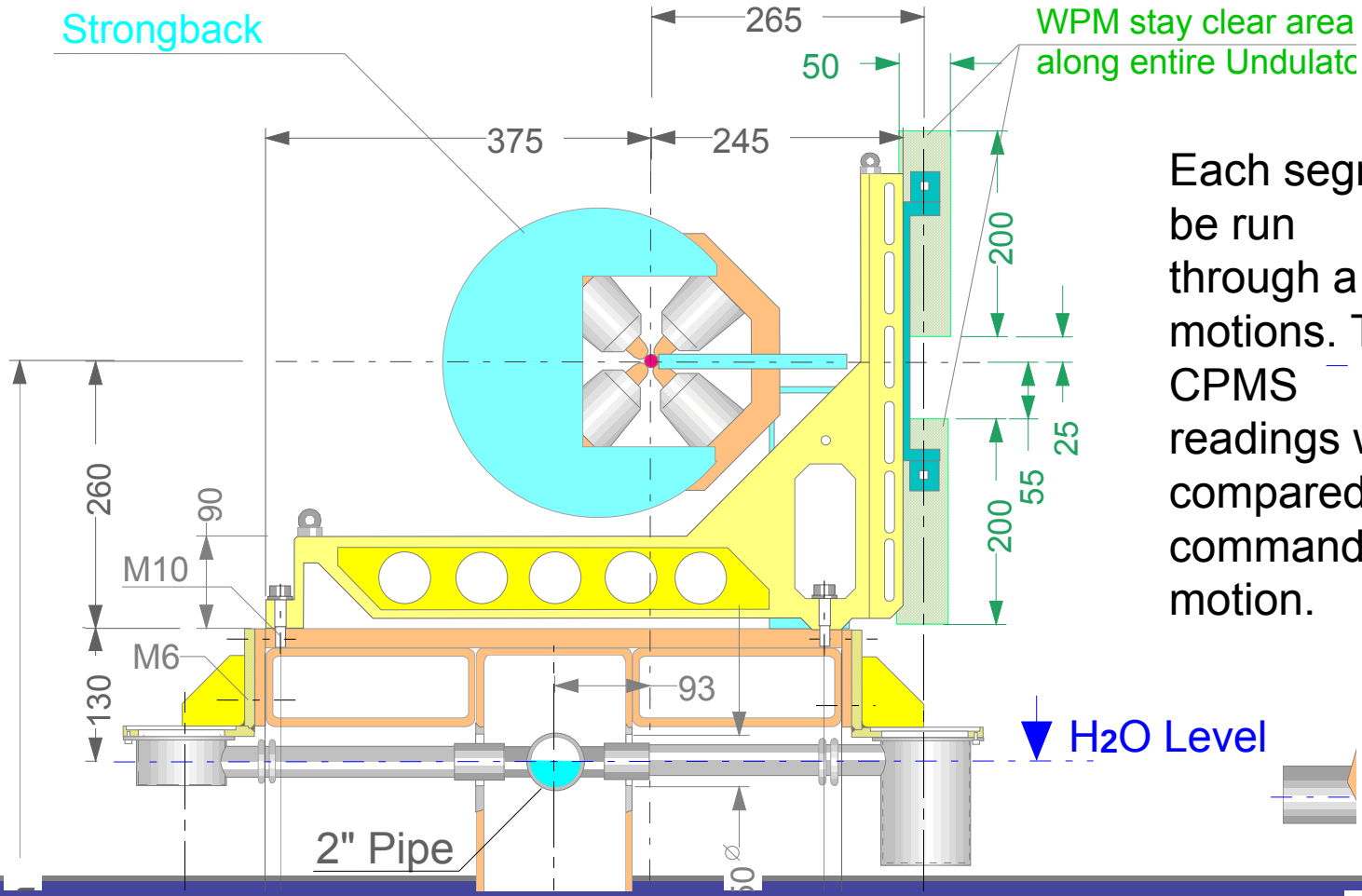


James Welch
Welch@SLAC.Stanford.edu

Motion Control System



Component Position Monitoring System



Each segment will be run through a series of motions. The CPMS readings will be compared with commanded motion.

Undulator Commissioning with Beam

- Start with undulator magnets rolled out, commission:
  - RF BPM's
  - Beam Finder Wires
  - Feedback systems
  - BBA system
  - MPS (machine protection system)
  - **BBA (beam based alignment procedure)**
- Roll magnets back in and redo BBA

BBA Procedure

- Basic Idea: Remove Dispersion
  - Measure trajectory for 3 different machine energies: 5.3 GeV, 6.5 GeV, 13.6 GeV
  - Correct dispersion by moving quadrupoles
  - Repeat process ≈ 3 times
  - Yields very straight, very smooth trajectories with low FEL phase errors.

FEL Beam Commissioning Goals

- Phase I - Spontaneous Radiation (SR)
  - Relaxed beam requirements: $\gamma\varepsilon$ < 4 μm, peak current > 100 A.
  - Commission x ray diagnostics and measure SR properties.

FEL Commissioning Goals (cont.)

- Phase II - FEL Radiation
  - Near design quality beam: $\gamma\varepsilon_{slice} < 1.2\ \mu m$, peak current ≥ 3400 A.
  - Obtain SASE and measure FEL Radiation properties
  - "CD4" milestone
    - Establishes construction is complete
    - X Rays must reach the Far Hall, 10^6 ph/mm^2 0.1% BW in the FEE
- Phase III - Transition to Operation
  - Follows CD4 milestone
  - Full rep rate and FEL Radiation power levels

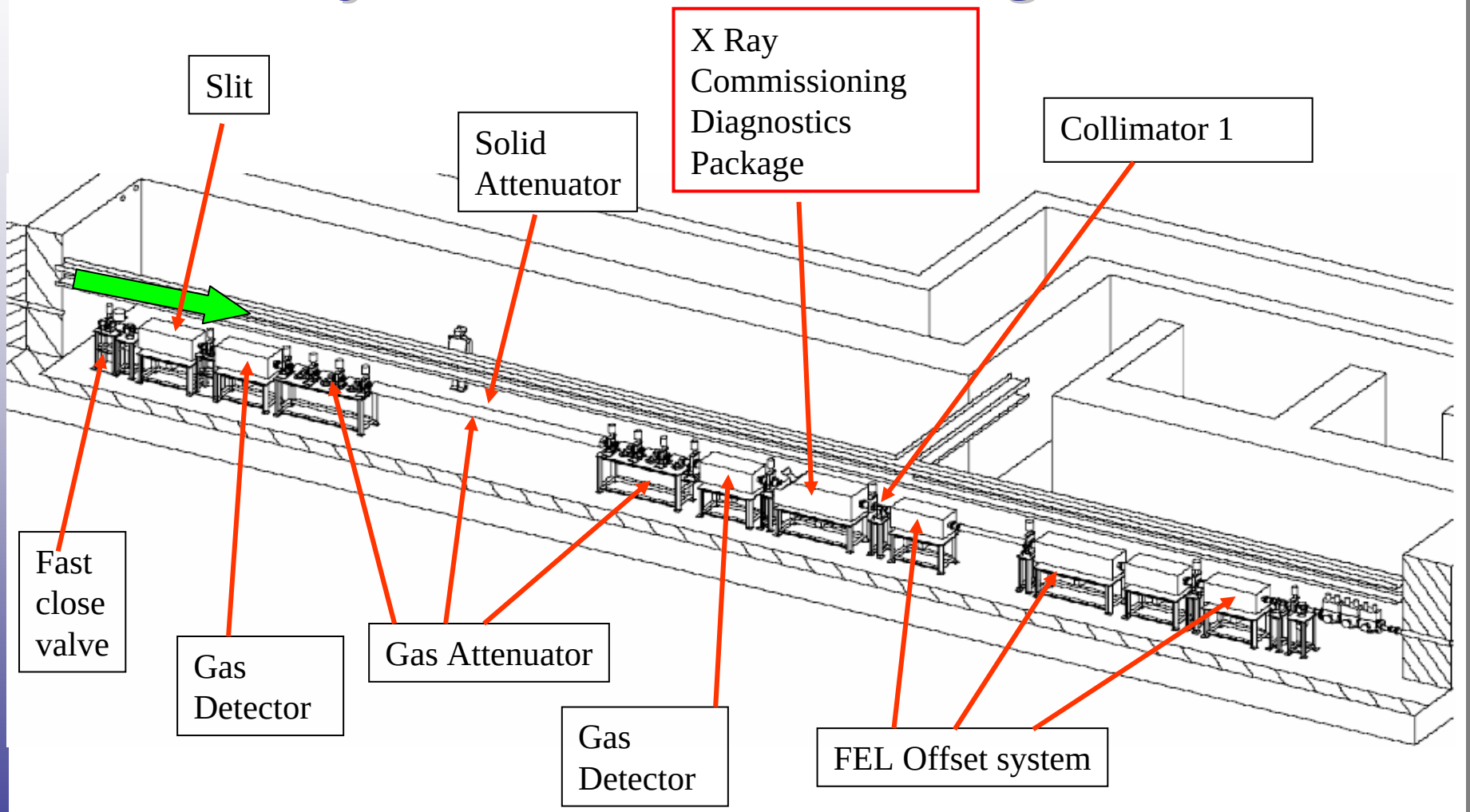
James Welch
Welch@SLAC.Stanford.edu

FEL Commissioning - Phase I

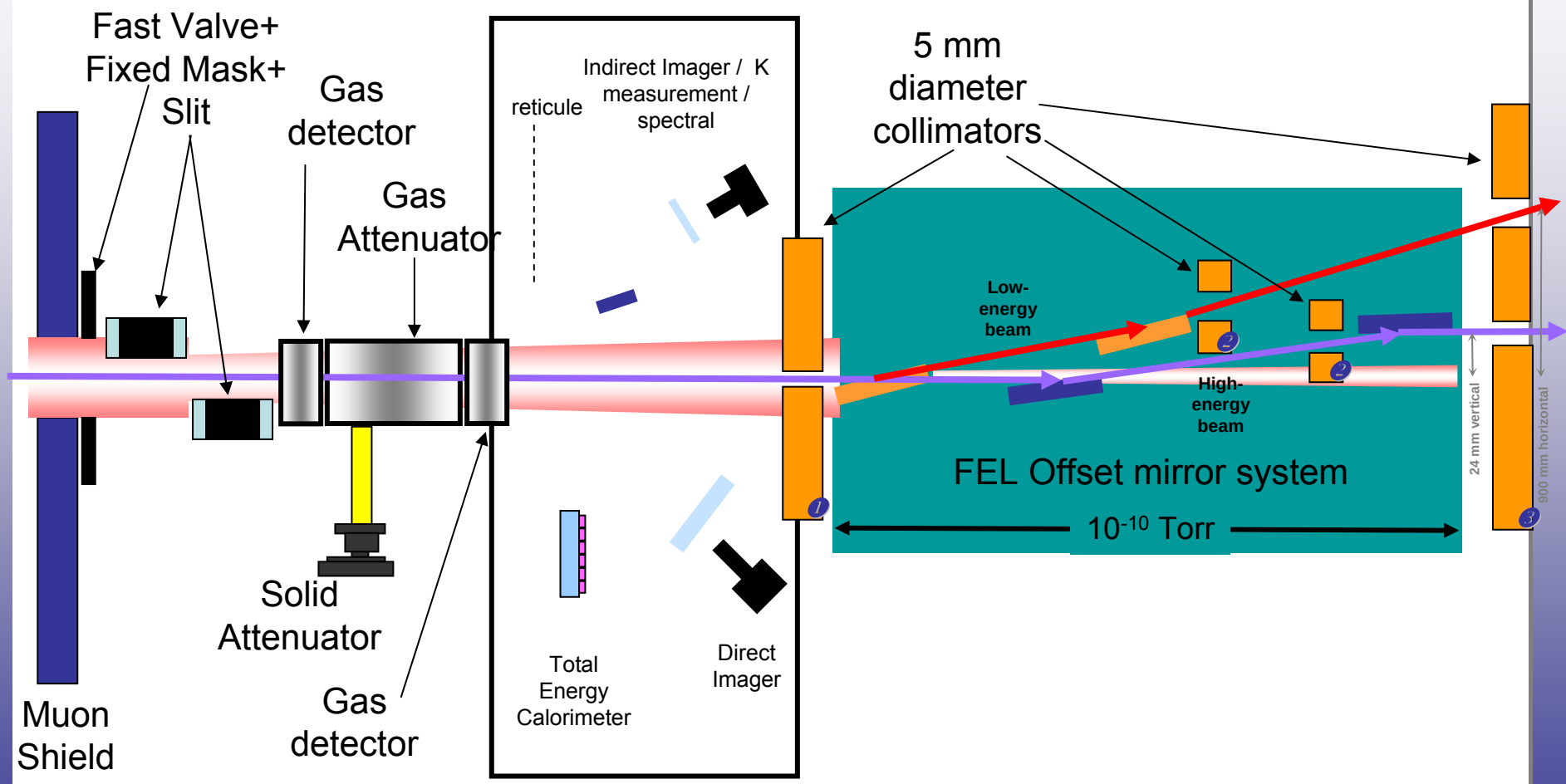
- Using SR only
  - **Verify apertures**
  - Commission X ray diagnostics
  - Characterize SR from individual segments
  - Characterize SR from entire undulator
- X Ray diagnostics commissioning is interleaved with FEL beam commissioning

James Welch
Welch@SLAC.Stanford.edu

X Ray Beamlines and Diagnostics



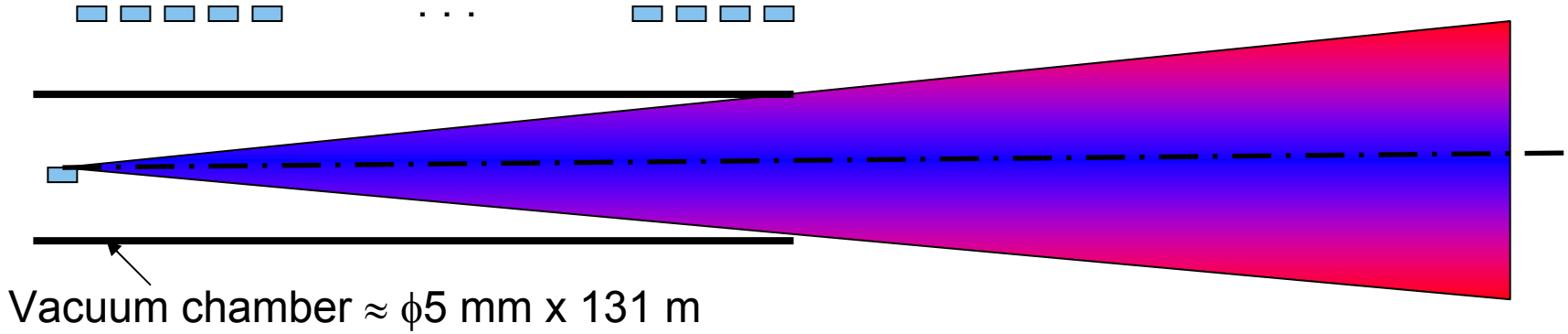
X Ray Diagnostics Package



Verify Apertures and Launch Angle

- Makes sure chamber is aligned with BBA determined trajectory.
  1. Steer launch angle to maximum photon energy in spectrum
     - Misaligned aperture will shift spectrum toward red
  2. Interpret spatial distribution

Only first segment is inline, 32 segments “rolled out”



Vacuum chamber ≈ ϕ5 mm x 131 m

Verify Apertures and Launch Angle

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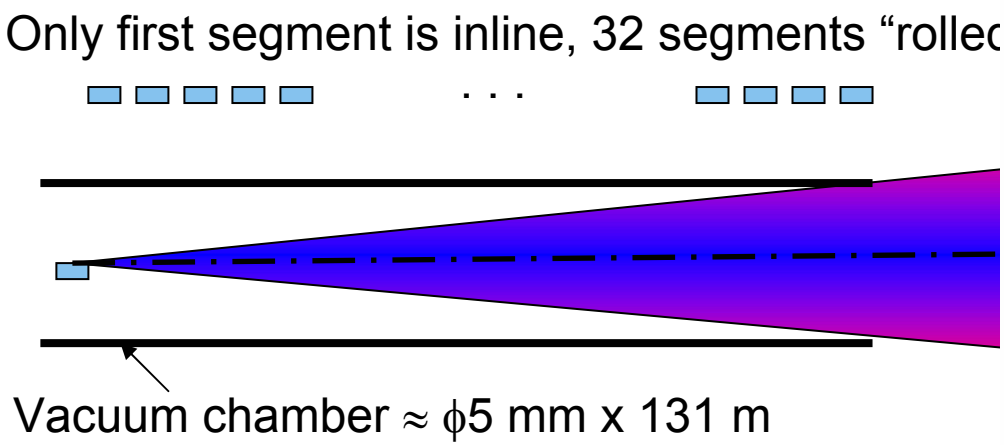
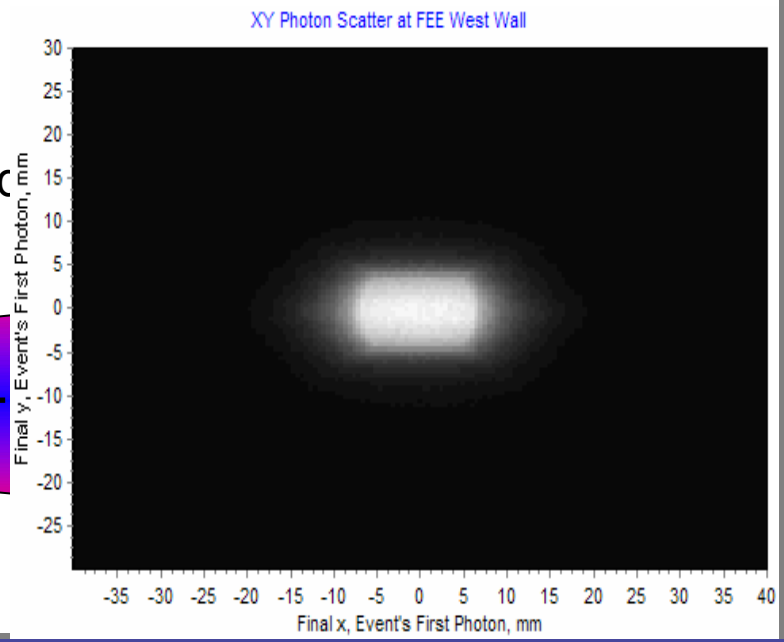


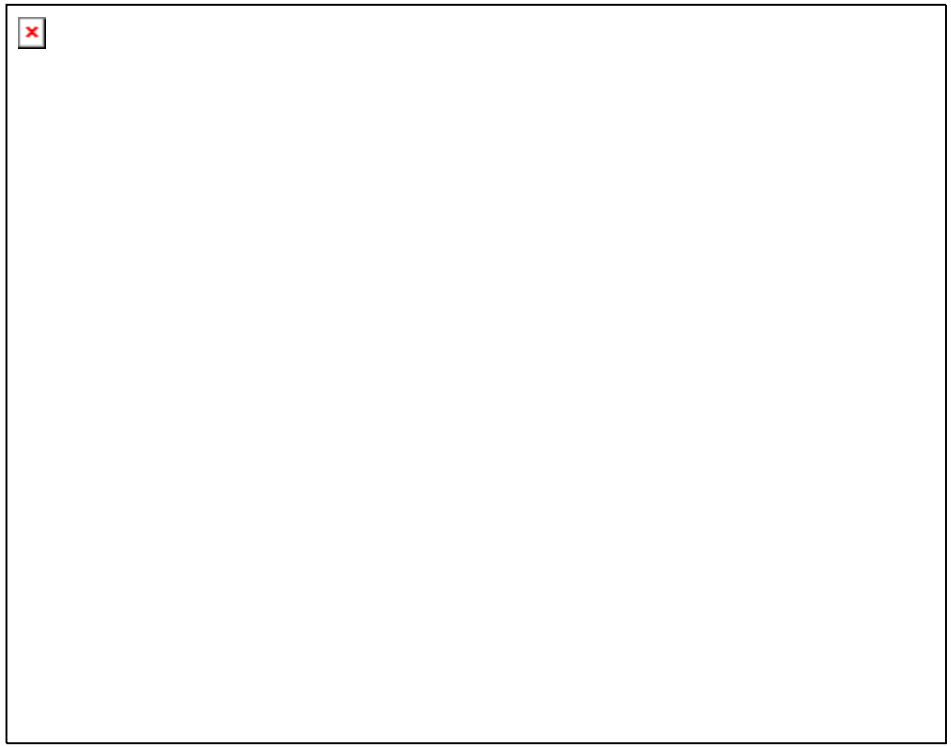


Strong Energy-Angle Correlation

- Spectrum shift measurement can be used to determine very small angles
- Angle integrated spectrum may be used to avoid strong dependence on observation angle.

$$\lambda_1 = \frac{\lambda_u}{2\gamma^2}\left(1 + K^2/2 + \gamma^2\theta^2\right)$$

1 microradian = 1 part in 10^4



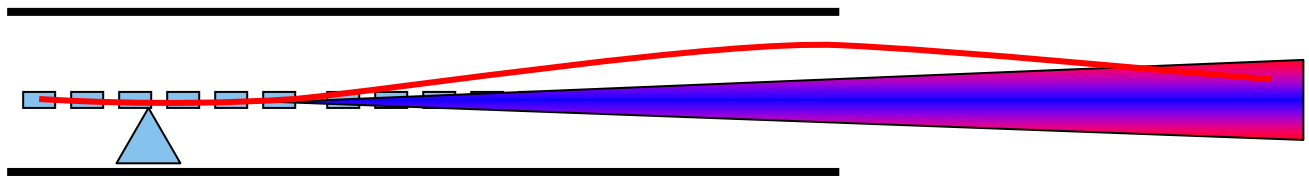
FEL Commissioning - Phase II

- Using FEL Radiation, at various energies
  - Find SASE signal
  - Calibrate diagnostics
  - **Measure Gain Curves**
  - Measure spectrum
  - Taper studies
  - Optimize gain
  - Get FEL Radiation on Mirror 1

James Welch
Welch@SLAC.Stanford.edu

Gain Curve Measurement (1)

1. Trajectory bump method

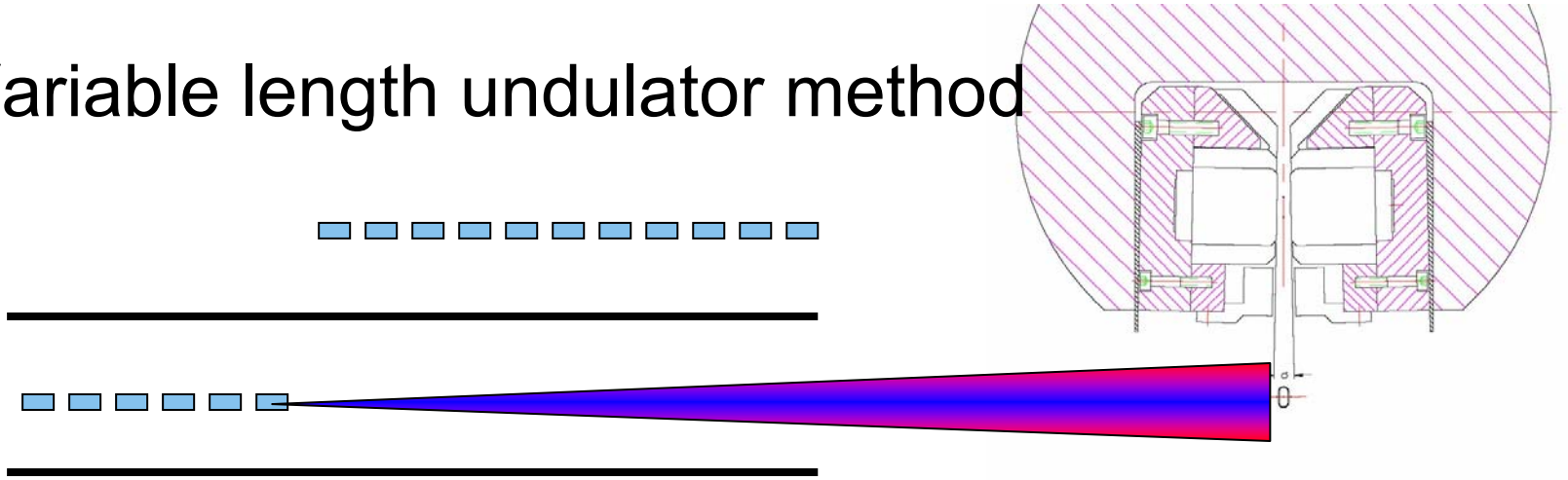


FEL Radiation alone is “turned off” by distorting orbit with a single corrector.

Spontaneous radiation is more or less constant.

Gain Curve Measurement (2)

- Variable length undulator method



SR and FEL radiation are both “turned off” by removing segments

Commissioning StudiesUnder Developement

- K measurement - 1 segment method
- K measurement - 2 segment method
- Orbit measurement
- Taper/beam energy measurement
- Histogram FEL energy
- Jitter studies
- Laser heater studies
- Microbunching instability studies
- Mode size studies
- Number of modes
- Optimizing FEL gain
- Number of spikes
- Reflection studies
- SASE bandwidth as a function of z
- Slotted foil studies
- Spatial measurements of SR
- Spatial measurements of FEL
- Spectral measurements of SR
- Spectral measurements of FEL
- SR energy vs charge
- Undulator taper measurements
- Trajectory sensitivity studies
- Transverse coherence
- Wakefield studies
- FEL pointing studies
- FEL pointing stability studies

James Welch
Welch@SLAC.Stanford.edu

Conclusion

- LCLS commissioning starts this year, with full beamline commissioning starting in March 08
- We have many new and sophisticated devices and systems that most be brought up to spec.
  - Laser,rf gun, x band, BCs,Undulator motion control, CPMS,…
- Commissioning demands advanced diagnostic techniques
  - Slice parameters
  - Bunch lengths
  - SR and FEL radiation properities

James Welch
Welch@SLAC.Stanford.edu