Commissioning the New LCLS X-band Transverse Deflecting Cavity with Femtosecond Resolution

Patrick Krejcik,

Christopher Behrens, Franz-Josef Decker, Yuantao Ding, Josef Frisch, Zhirong Huang, James R. Lewandowski, Henrik Loos, James Turner, Juwen W. Wang, Min-Huey Wang, James Welch

SLAC NATIONAL ACCELERATOR LABORATORY

Motivation

An exact knowledge of the pulse duration and temporal profile of the x-ray beam on a pulse-by-pulse is vital for many of the ultrafast experiments at LCLS

directly measure the pulse length at the femtosecond level

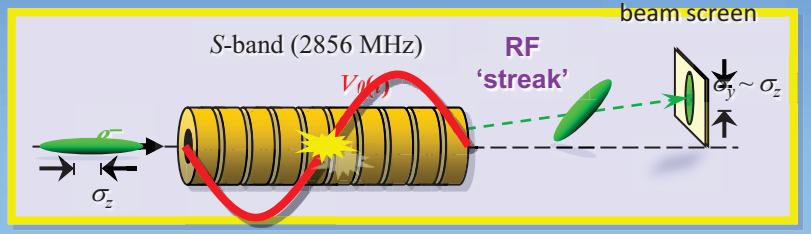
reconstruct the x-ray temporal profile

Non-invasive

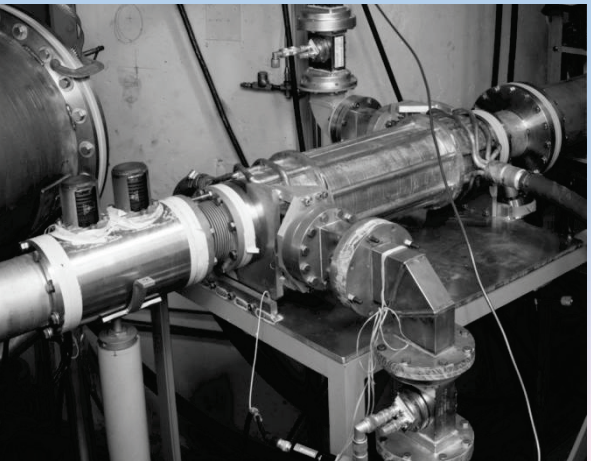
Every pulse at 120 Hz

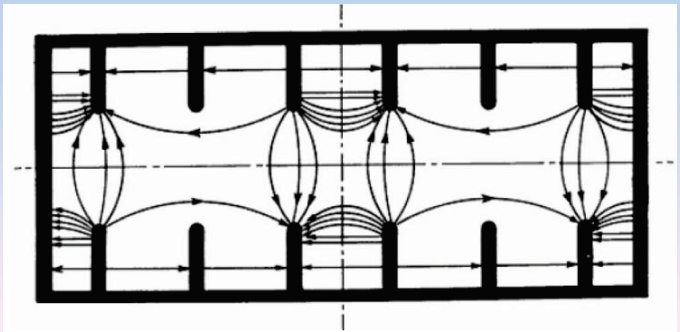
Femtosecond resolution

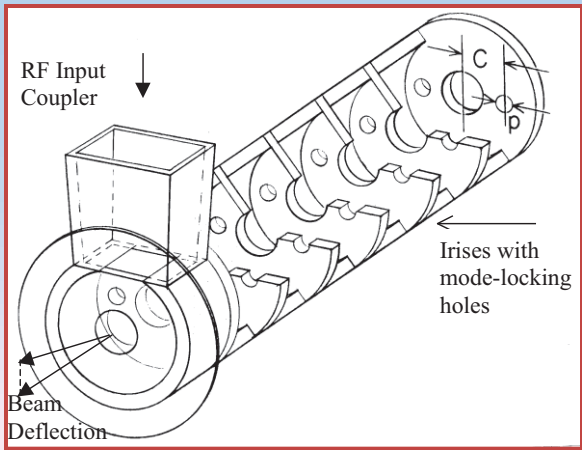
Transverse Deflecting Structures



- Well-established technique at SLAC to measure bunch length.
- Use a time-varying transverse electric field to "streak" the beam across a monitor screen.
- 3 m long S-band 2856 MHz structures built in the 1960's can give a ~24 MV transverse kick
- Installed in the LCLS linac, but are invasive to operation for photon users.





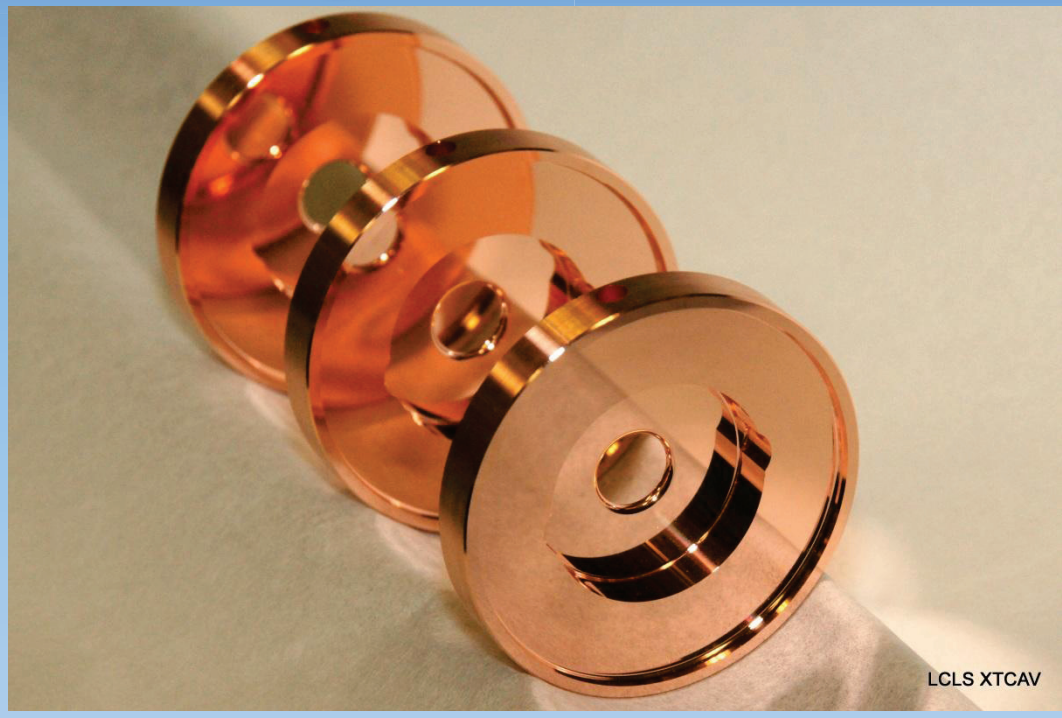


XTCAV Differs in 3 Important Respects

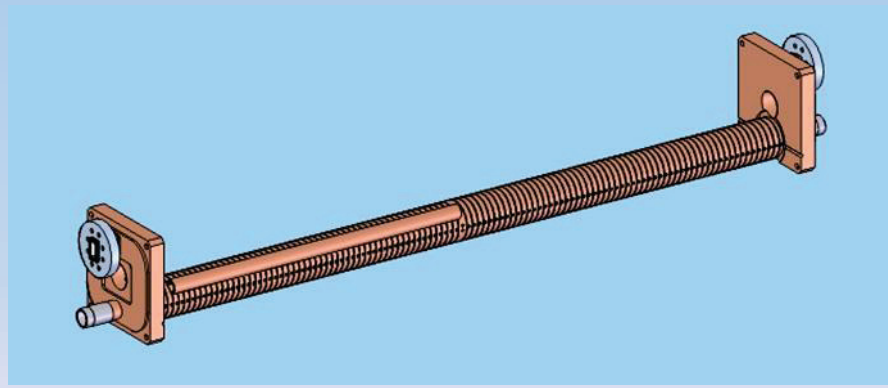
- Operates at 11.424 GHz and gives 8 times better temporal resolution
  - Factor 4 from shorter wavelength and twice the voltage
- Located downstream of the undulator and cannot interfere with photon operation
  - Continuous operation at 120 Hz
- Reconstruct the temporal profile of the x-ray beam from the energy loss profile of the electrons
  - Compare the FEL off and FEL on images

The Challenges

- The x-band microwave structure is made up of copper “cups” diamond machined to micron precision and diffusion bonded into 1 m long structures

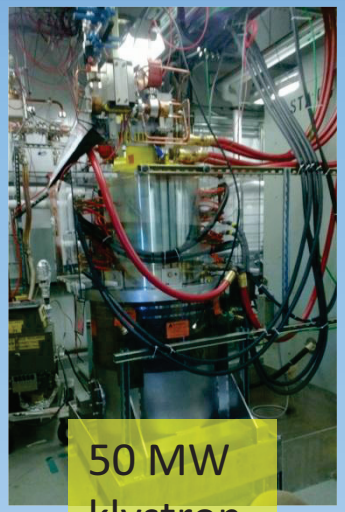


- Each of the **113 cells** is RF tuned at the tunnel operating temp. of 20 ° C

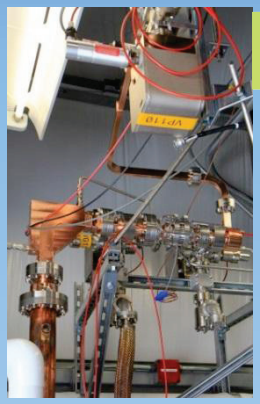


- The structures were pre-assembled on an optical bench and aligned to 50 um

Two-year, $5M Project Began Operation May 2013

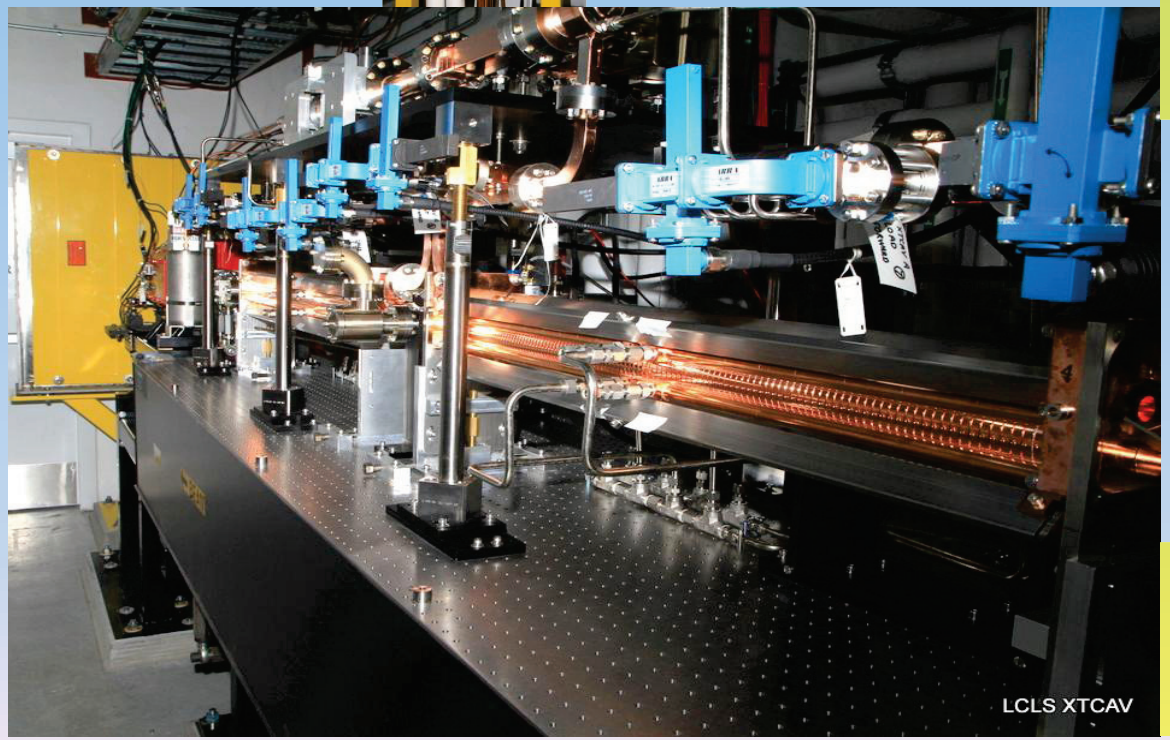


50 MW klystron



waveguide

Controls: PAC, PADS, MKSU

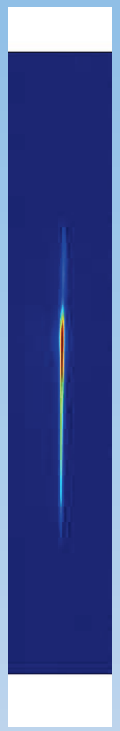


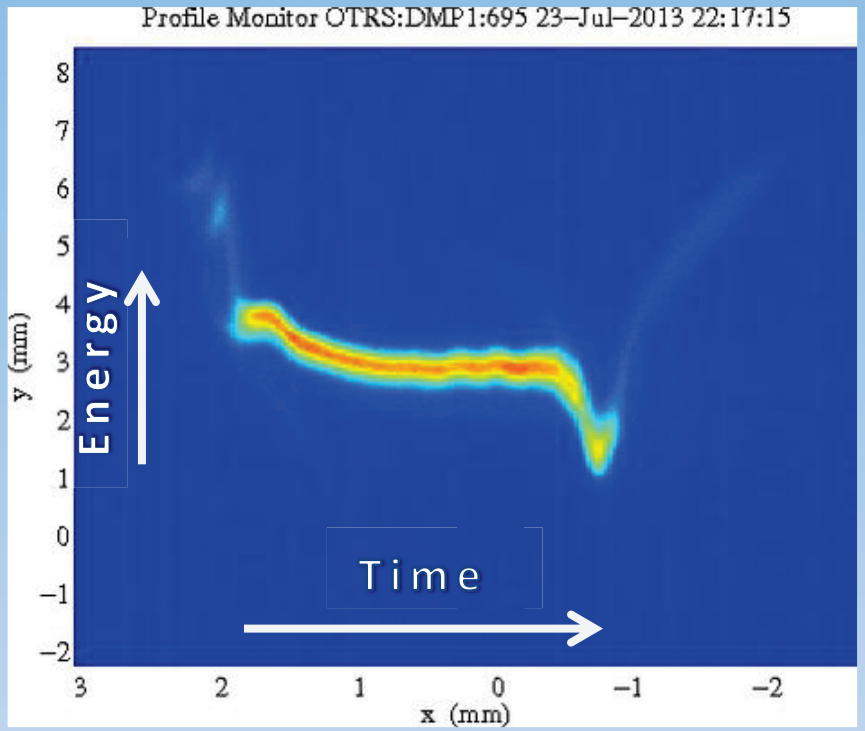
430 kV modulator

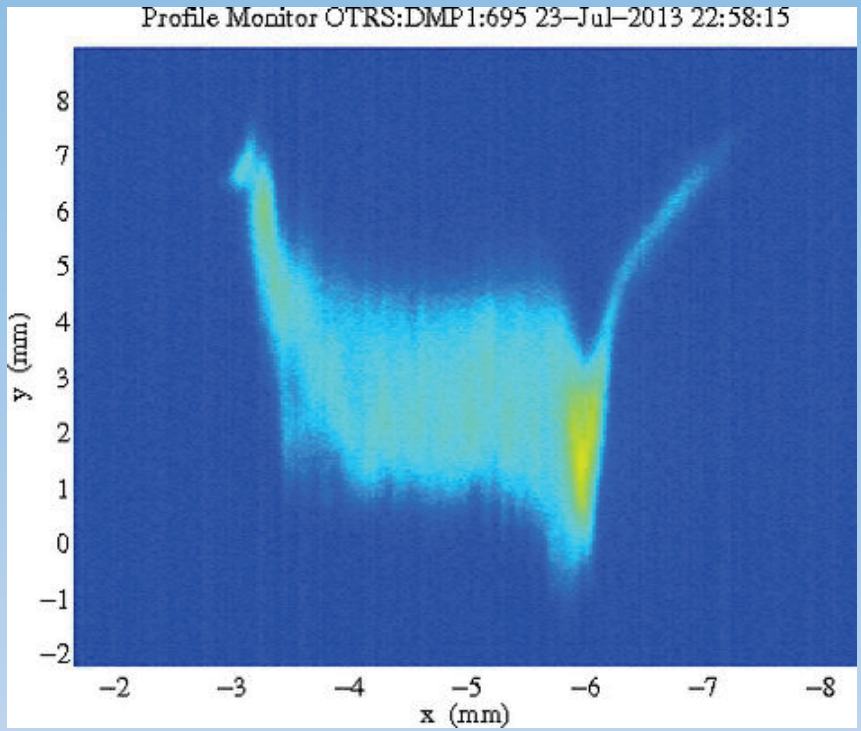
LLRF Drive: TWTA, klystron Mag. Suppl.

Measurement examples: 4.7GeV, 150pC (1keV)

Three Images at the e-dump spectrometer screen





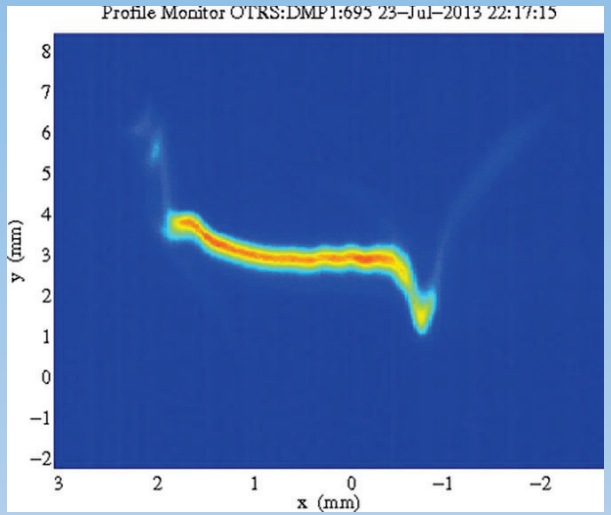


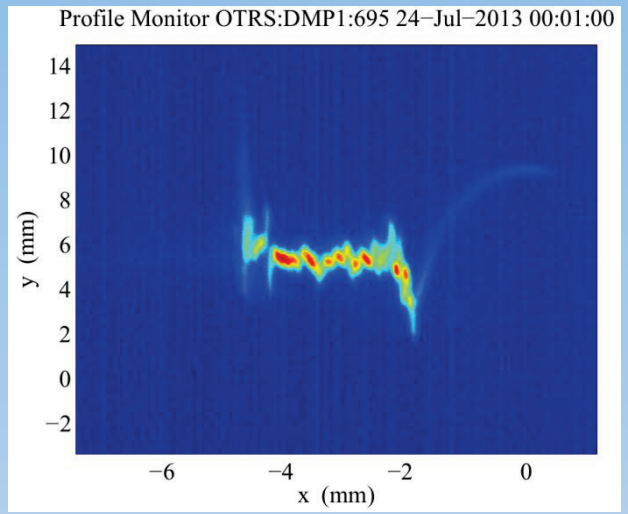
XTCAV Off

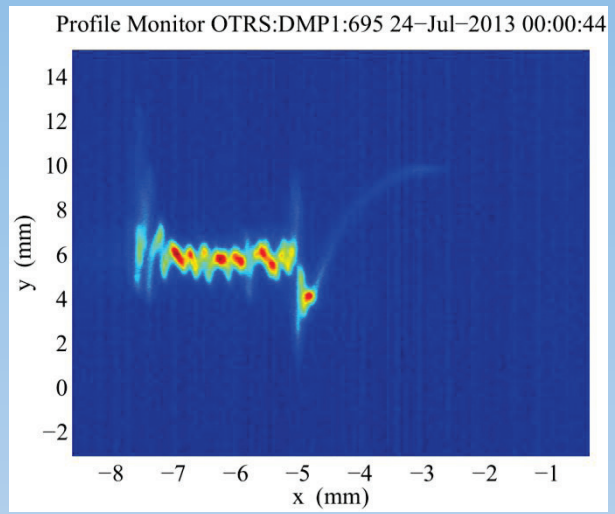
XTCAV On FEL Off (baseline)

XTCAV On FEL On ~1mJ FEL pulse energy

Direct Observation of Microbunching Instability







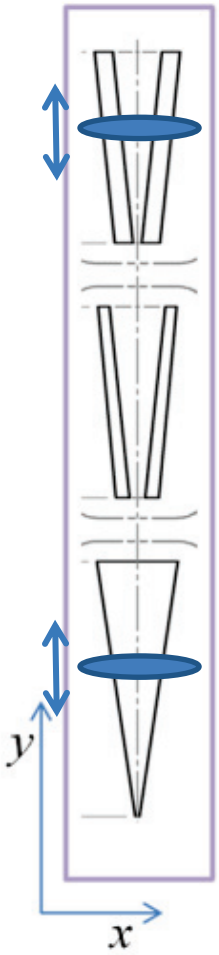
Decreasing gain on the Laser Heater

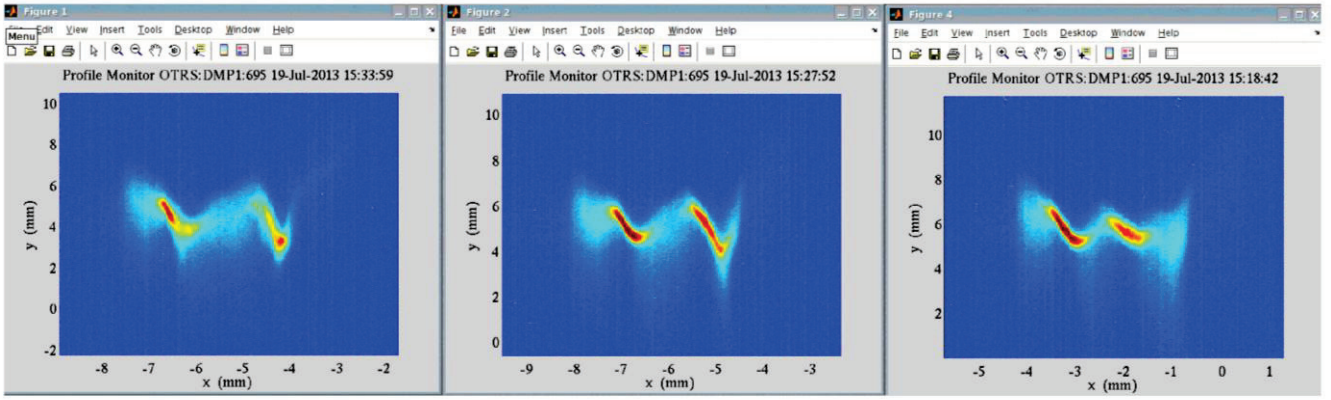
Slotted-foil examples (lasing off)

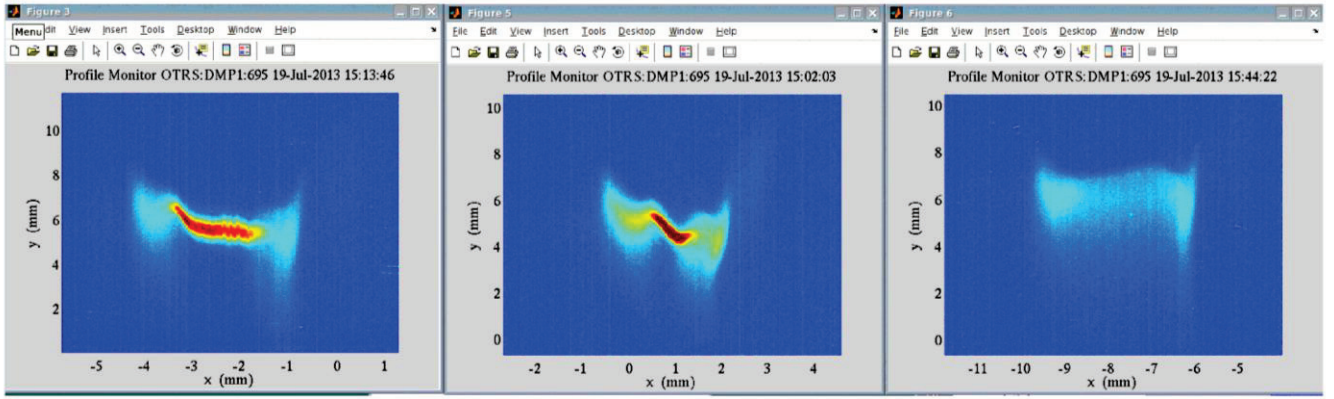
shows clearly the unspoiled beam region

Double Slit

Single Slit

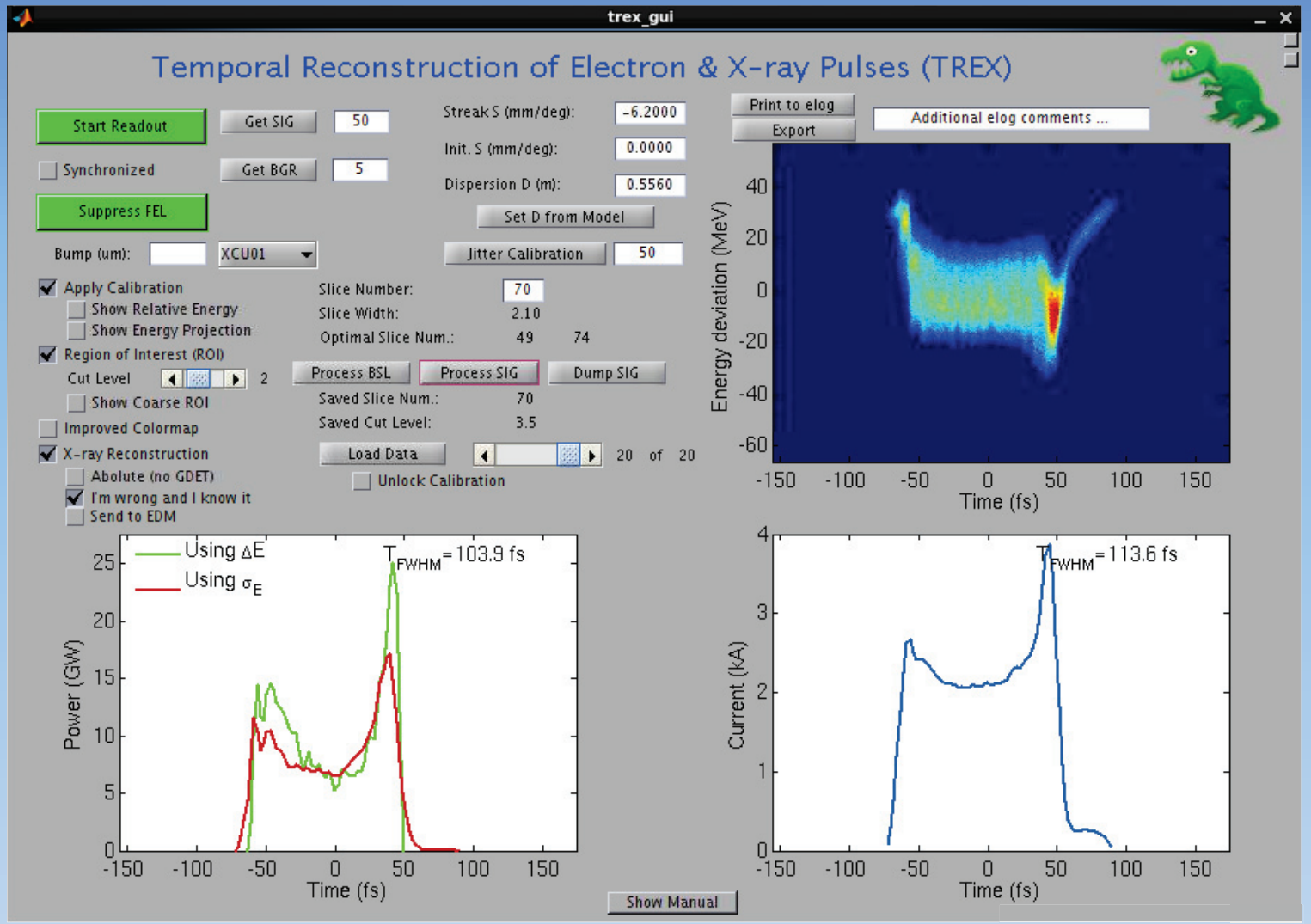






4.7GeV, 150 pC

Single shot data processing



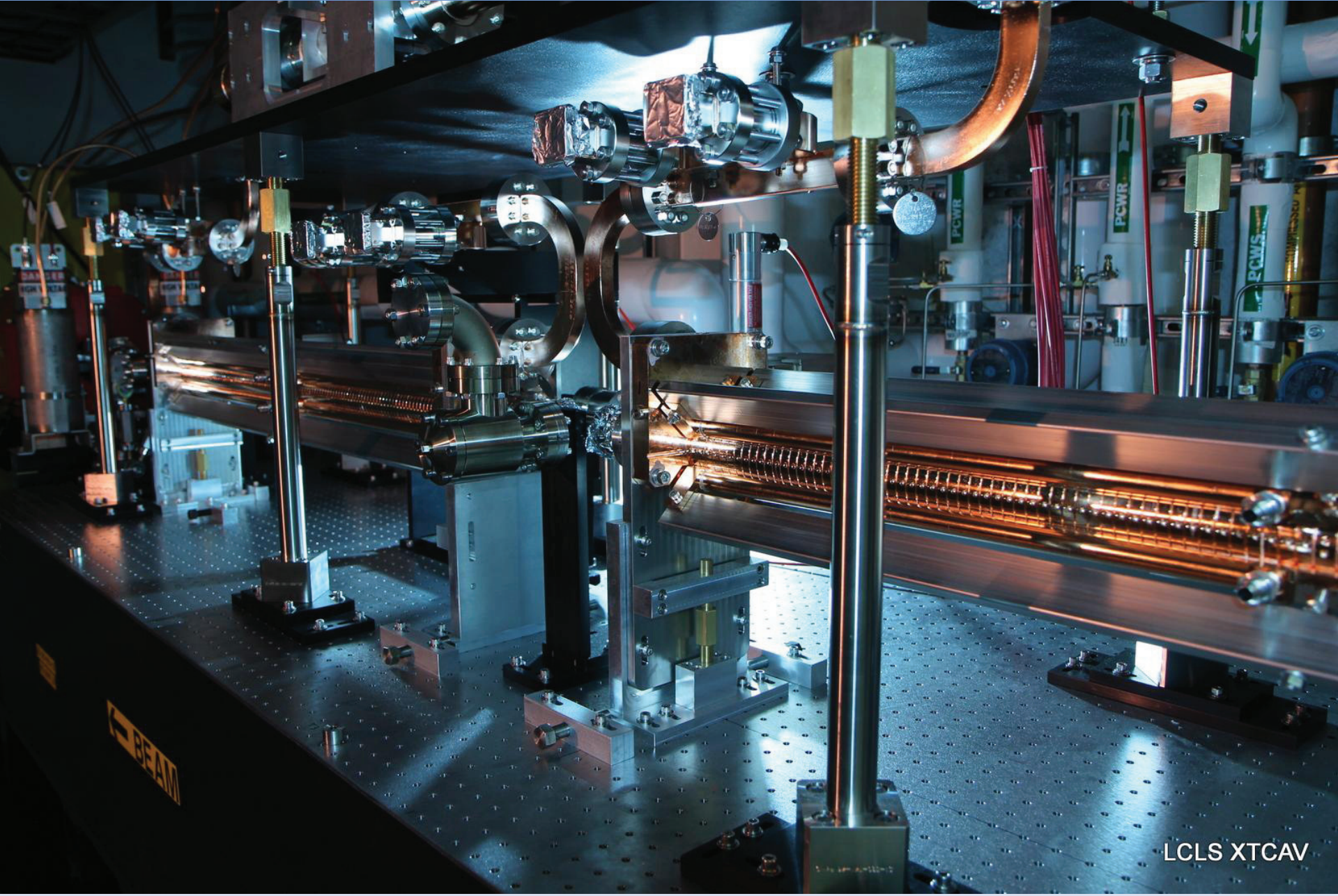
- Calibration;
- Record baseline images (FEL-off);
- Image processing, slicing and averaging baseline data;
- Take single-short image (FEL-on) and other beam parameters;
- Reconstruct electron and x-ray temporal profile.

(C. Behrens)

Summary and outlook

(Note – some slides removed pending publication)

- Demonstrated resolution of 1.3 fs
- XTCAV provides non-invasive monitoring of longitudinal phase space at 120 Hz
  - quantitative measurement,
  - absolute calibration
- Directly observed
  - SASE evolution
  - Chirp and bunch compression dynamics
  - Microbunching
  - Slotted foil
  - Selfseeding
- Upgrade data acquisition to stream 120 Hz measurements to photon users
- Upgrade RF power for enhanced resolution



Structure installed on bench before waveguide connected.

Acknowledgements

- we are indebted to the SLAC community for their contributions:

- P. Emma, J. Frisch and Z. Huang for their contributions and earlier work on TCAV systems
- H. Loos and C. Behrens (TREX) for the higher level applications
- J. Wang and V. Dolgashev for concept and design of the X-band structures
- Engineering: R. Akre, E. Bong, M. Boyes, S. Condamoor, J.P. Eichner, G. Gassner, A. Haase, B. Hong, A. Khalid, J. Lewandowski, B. Morris, J. Olsen, D. Sprehn, A. Wu
- And thanks to all of the XTCAV commissioning team!