FEE Diagnostics and Commissioning

June 17, 2008

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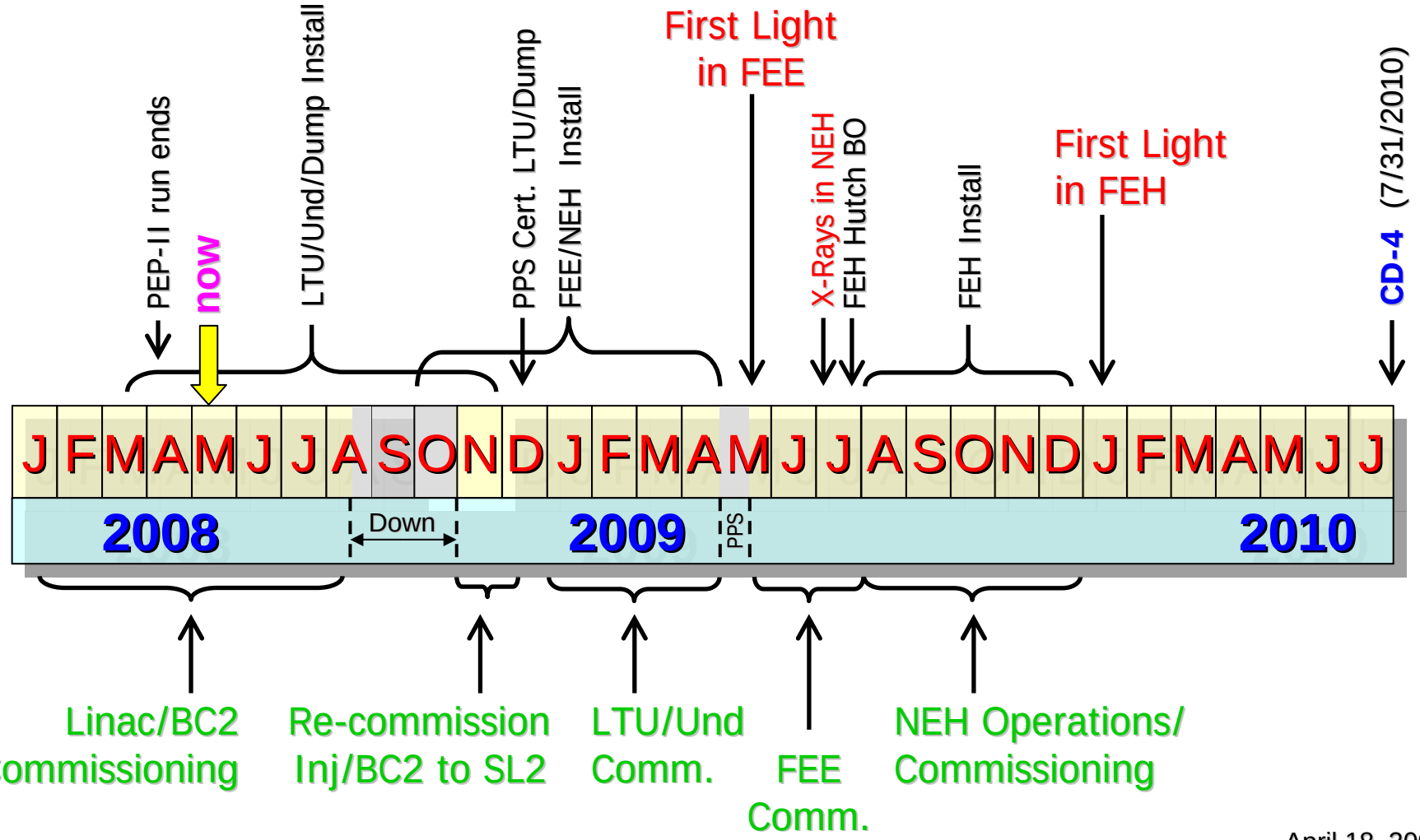
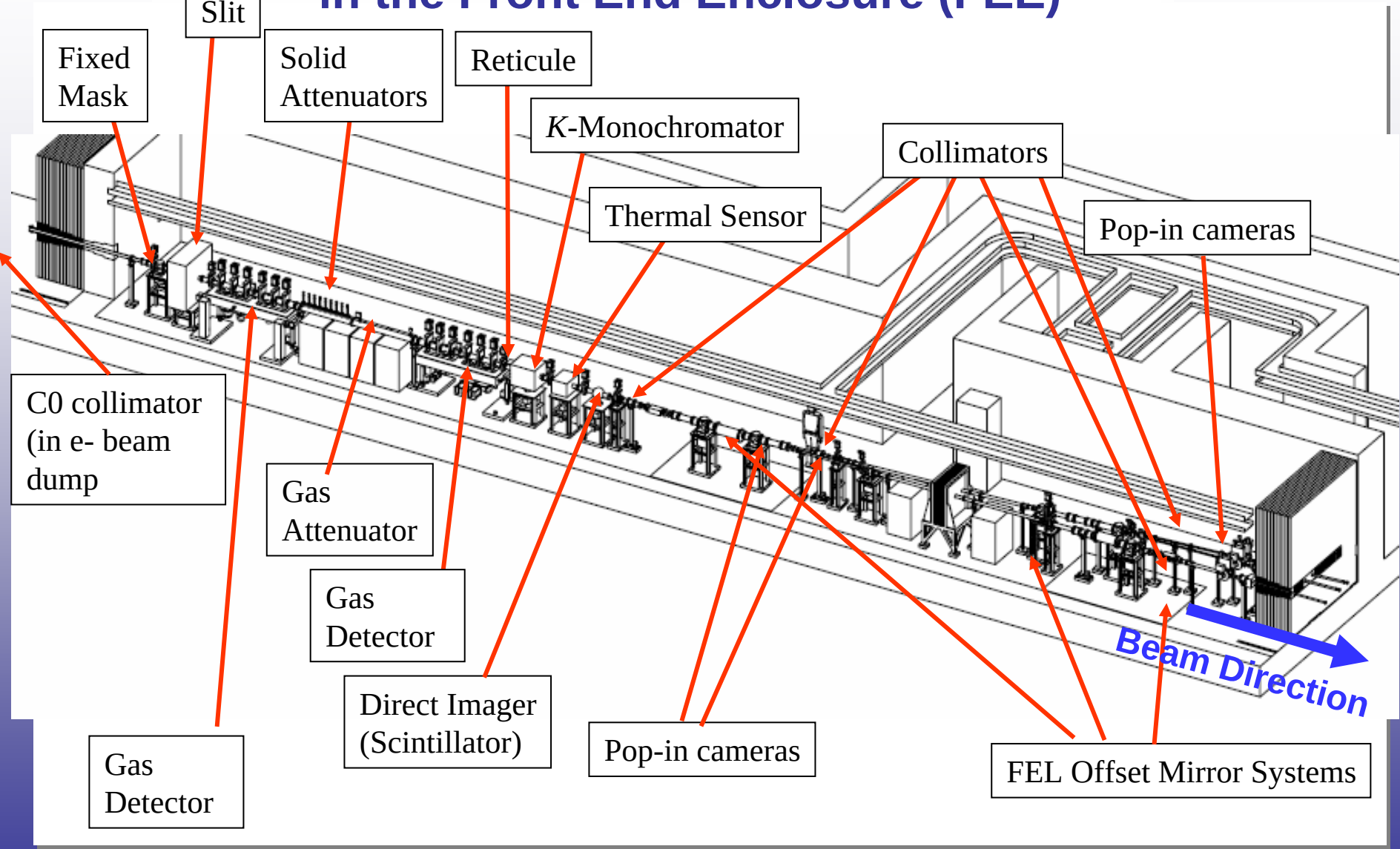
LCLS Installation and Commissioning Time-Line



April 18, 2008

XTOD Commissioning Diagnostics and Offset Mirrors in the Front End Enclosure (FEE)



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FEE pre-beam commissioning I (Mar-May 09)

- FEE HVAC System Checkout
- EPICS Control System Checkout
  - Network, Timing, and Server functionality
  - Basic IOC startup
  - Common Services
    - Archiving
    - Logging
    - gateways to/from e-beam
- Basic Services Checkout
  - Air system / valves
  - Water cooling
  - SOMS/HOMS temperature control
- Vacuum pump down of all devices
  - PLC ladder logic checkout
  - EPICS control and monitoring of controllers
  - Full cycles for instruments
  - State control for Gas Detector/Attenuator

FEE pre-beam commissioning II (Mar-May 09)

- Verification of individual Device Operation
  - Slit
    - Motion control
  - Gas Detector/Attenuator
    - Pressure control
    - Motion control
    - Solid Attenuator control
    - PMT & APD digitizer operation (triggering) and HV control
  - *K* monochromator
    - Motion control
    - Photodiode digitizer operation (triggering)
  - Thermal sensor
    - Motion control
    - Cooling control
    - Laser energy measurement and triggering
    - Sensor digitizer operation (triggering)
  - Direct Imager
    - Motion control
    - Camera operation (triggering) with UV illuminator

FEE Commissioning with Spontaneous, Single Undulator (May 09)

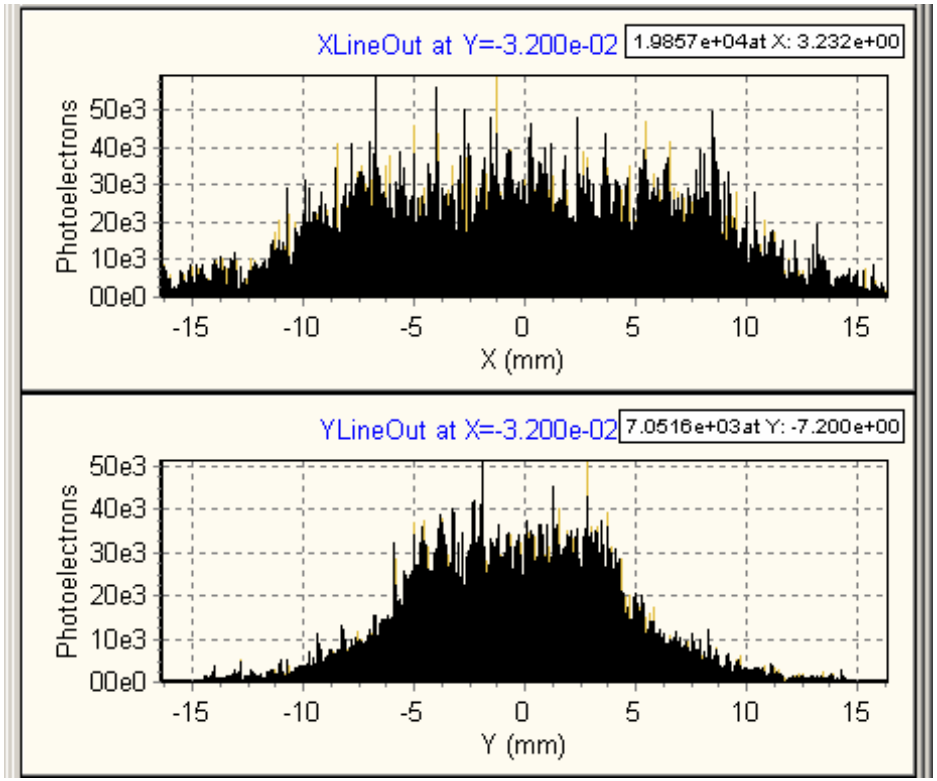
- RP Survey
- Measure centroids with Direct Imager
- Check positions of apertures
  - Fixed Mask, Slits, C0

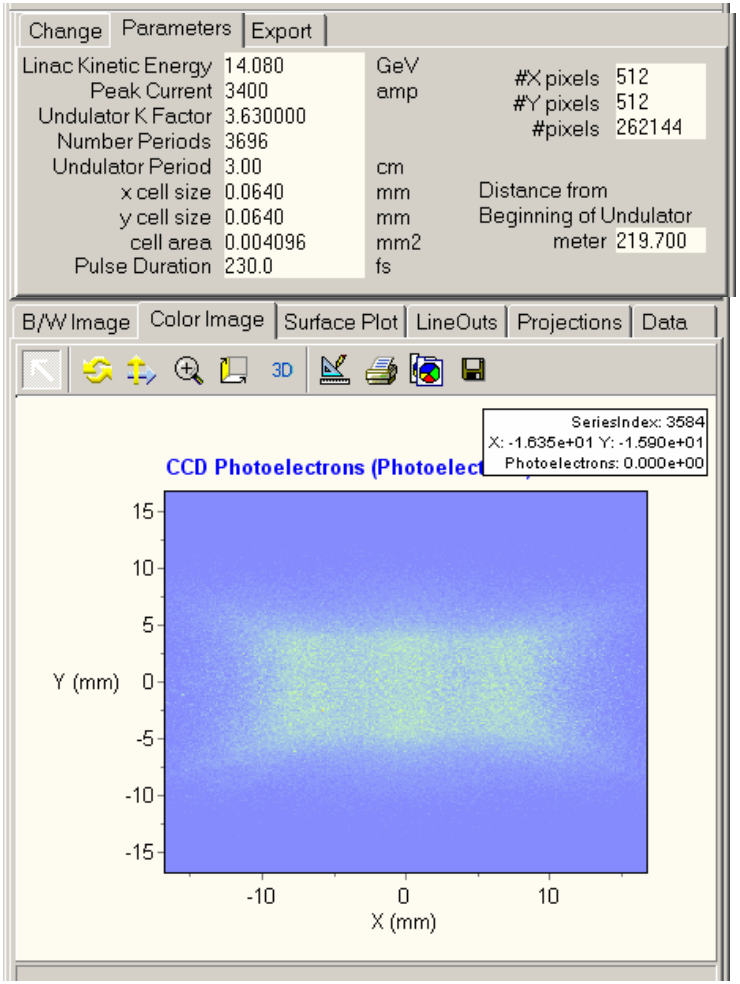
FEE Commissioning with Spontaneous, All Undulators at 13.64 GeV (May-Jun 09)

- RP survey and verification of apertures
- Insert reticule and center
- Commission Pop in 1
- Verify position of collimators
- Align Gas Attenuator Apertures
- Commission Gas Detector
- Commission Thermal Sensor
- Commission K-Monochromator
  - Measure flux in fundamental

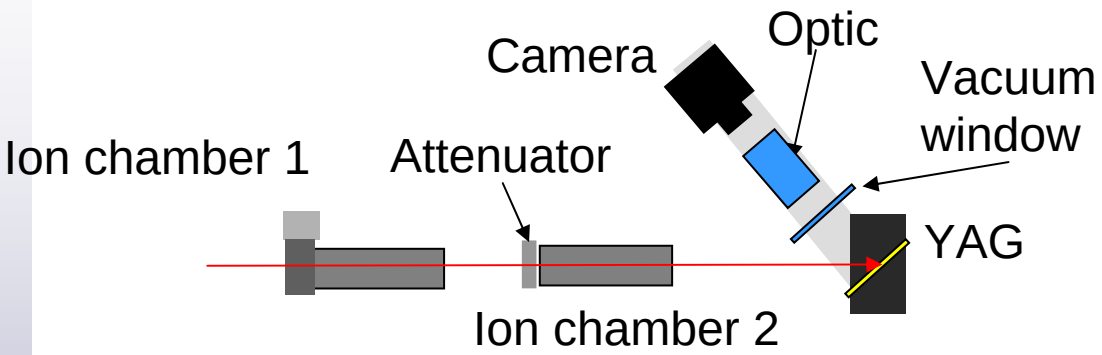
Hard X-Ray spontaneous, all undulator segments, viewed by Direct Imager

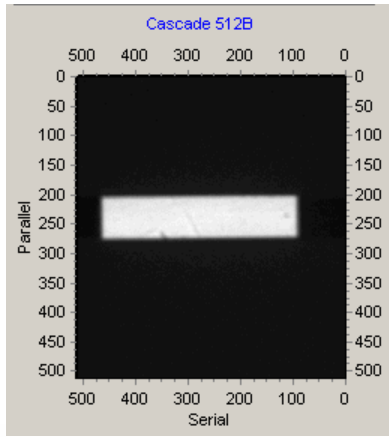
Absorbed in 50 microns YAG

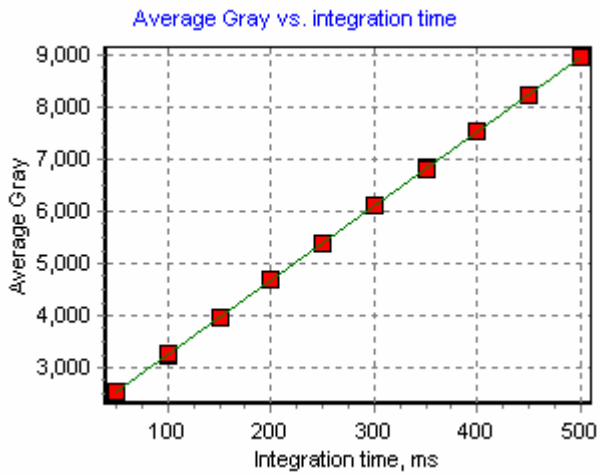


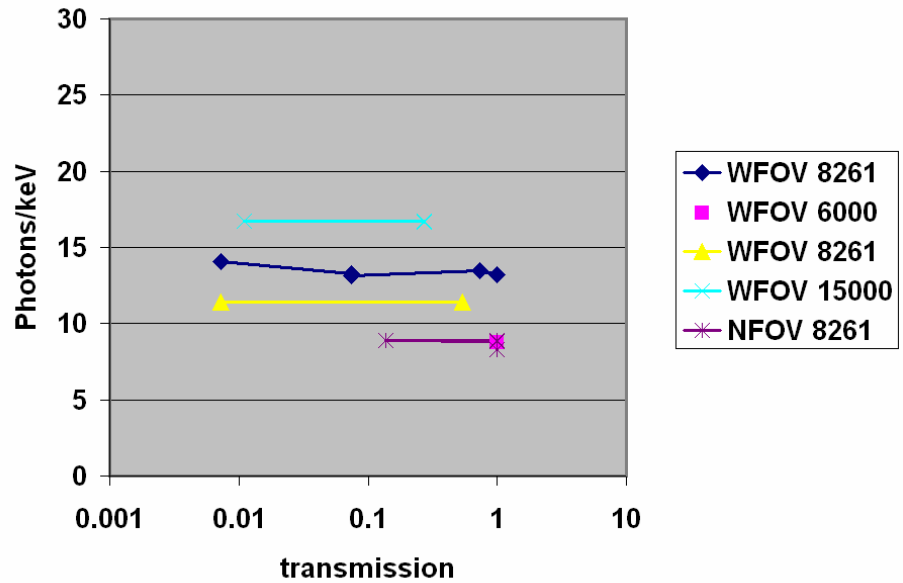


Measurements of Direct Imager YAG yield: 12 ± 3 photons / keV



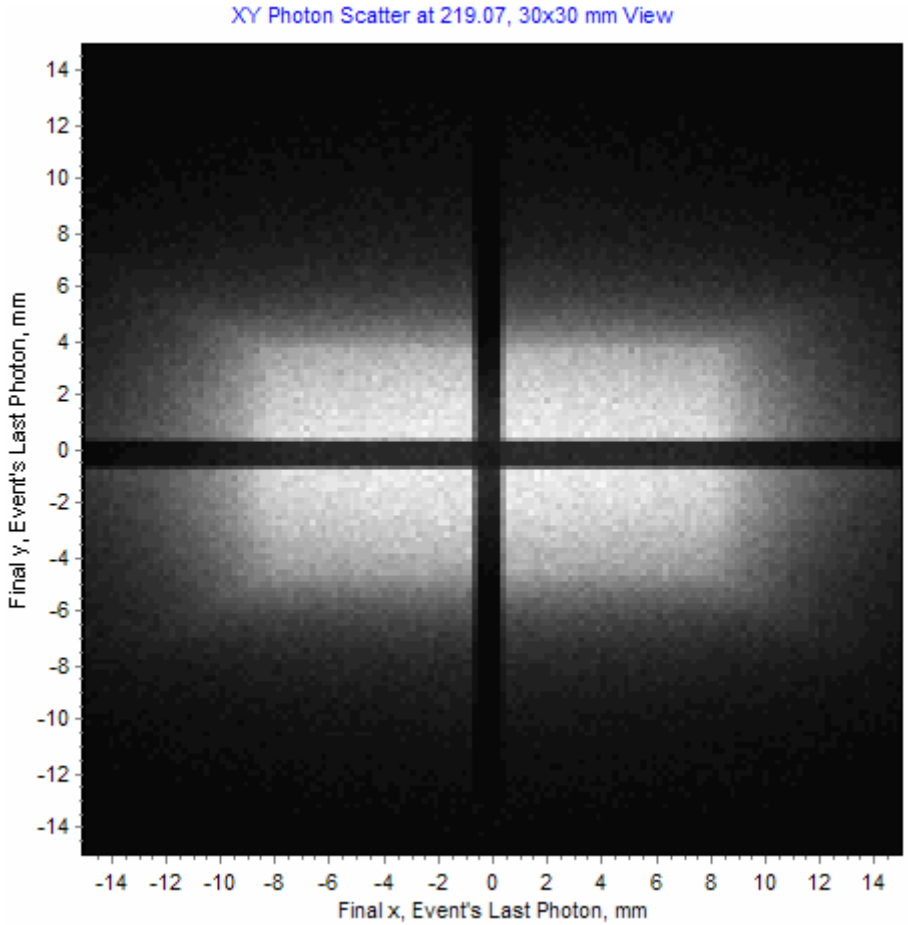




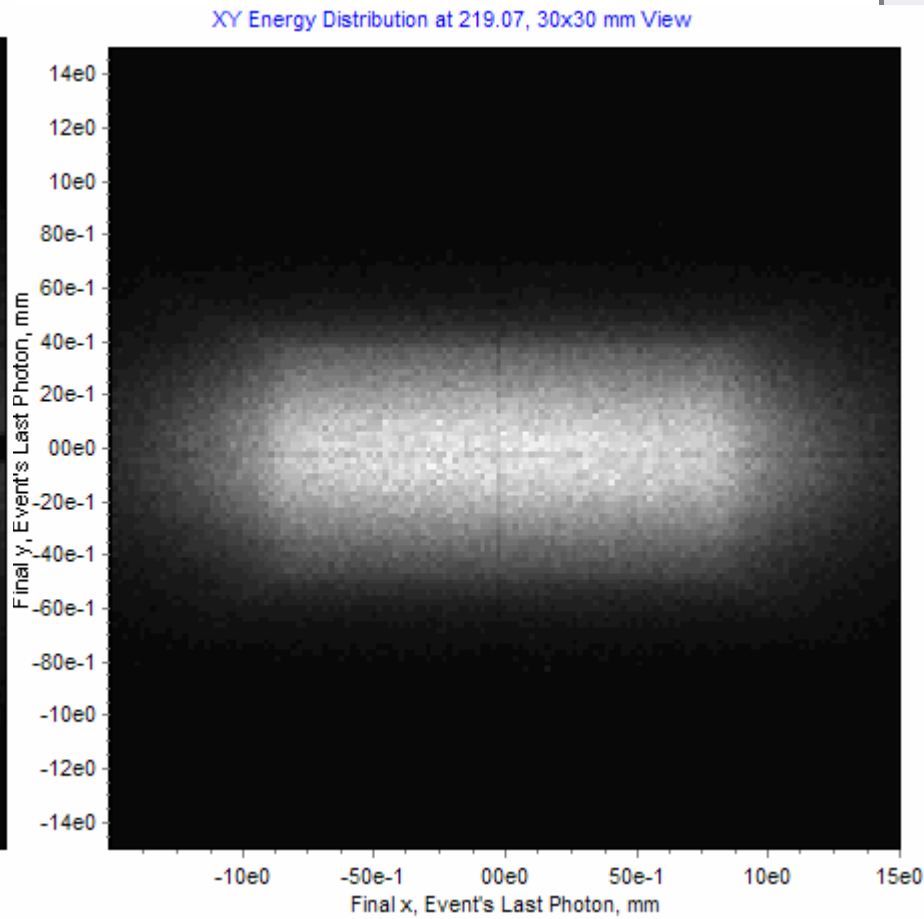


Reticules in Direct Imager

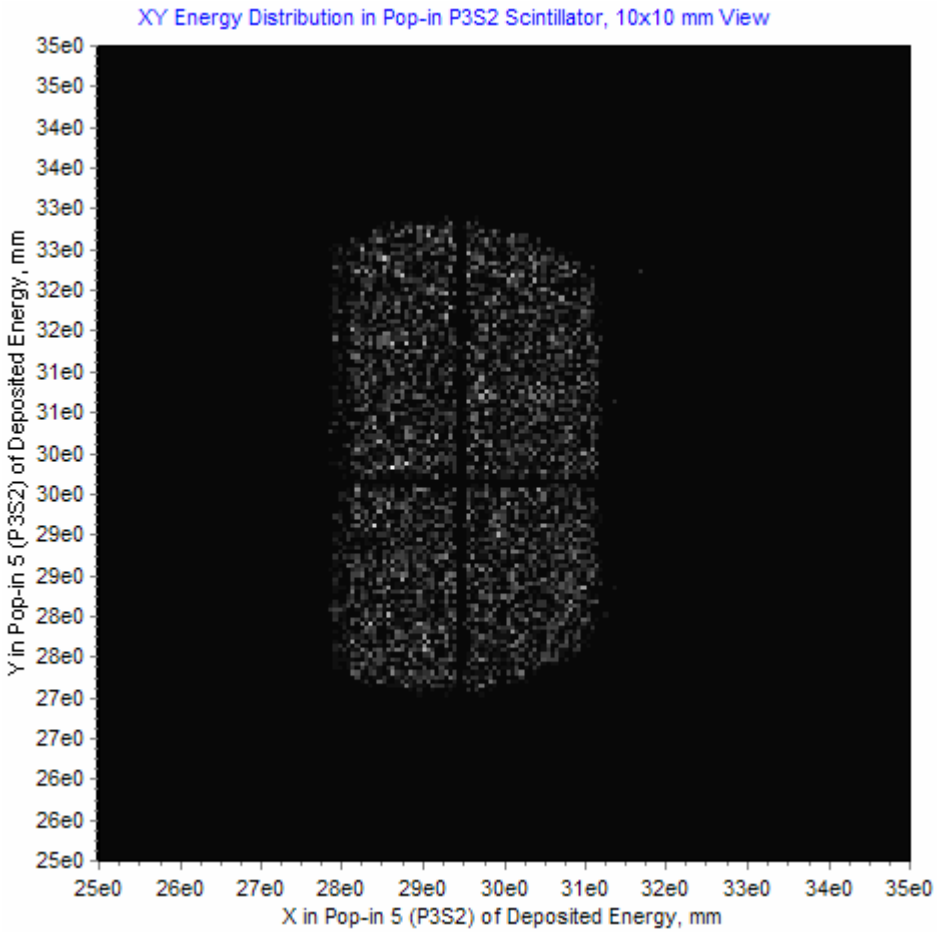
1 mm reticule



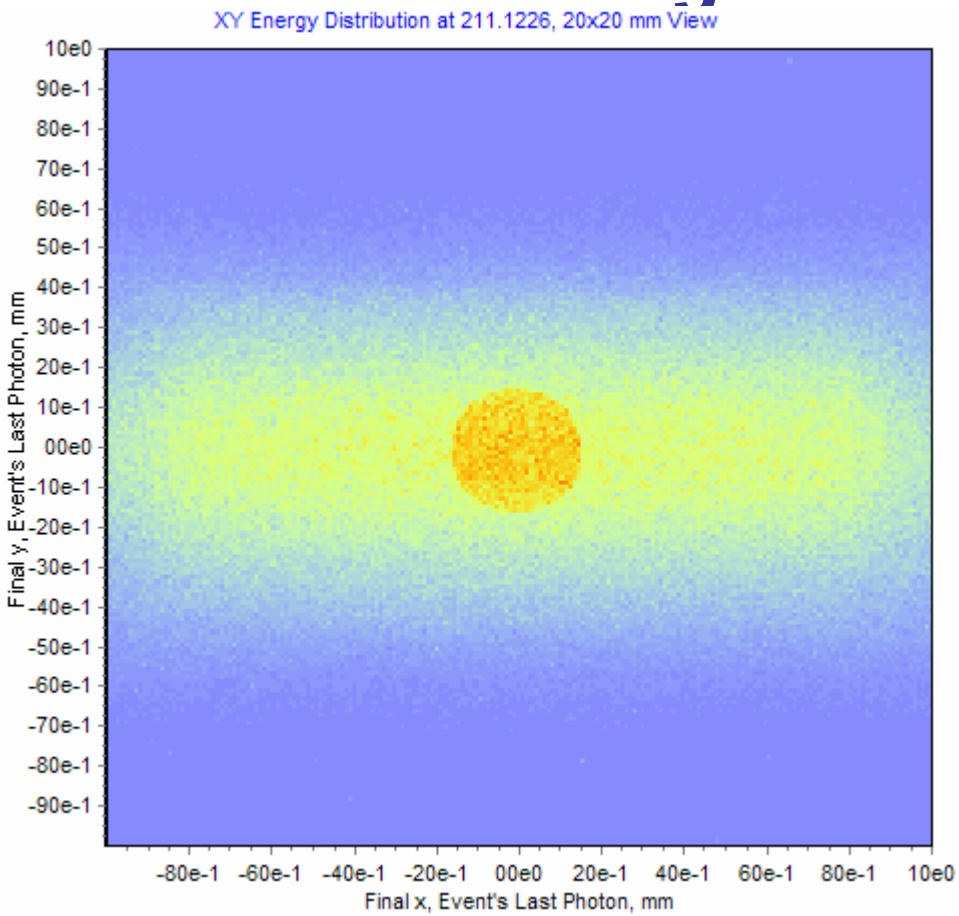
100 micron reticule



Reticules in Pop-in cameras



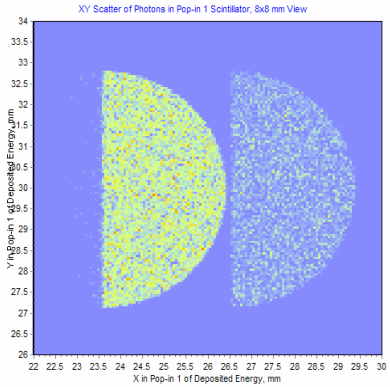
Alignment of Attenuator apertures with Direct Imager



Align Soft x-ray mirrors (Jun-Jul 09)

- Use Pop-in cameras with Spontaneous
  - A pop-in camera exists behind each mirror
  - Pop-ins can see reflected and not-reflected beam
  - Measure distance between reflected and non reflected beam to set angle
  - Translate mirror to center beam on mirror
  - Alignment can be performed with spontaneous radiation

Simulations of Pop-in imagery



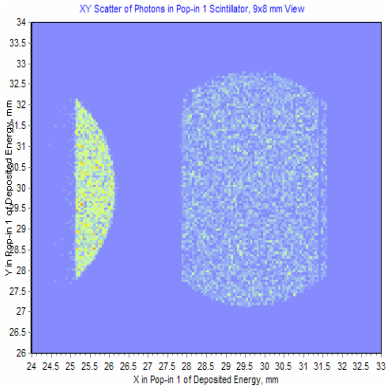
Δy = -1.737 mm

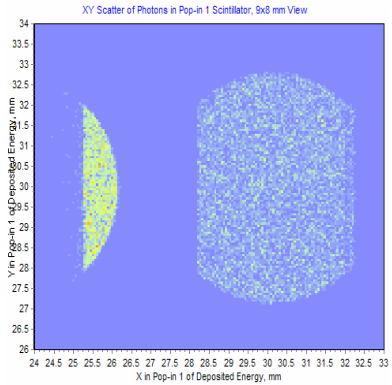
θ = 12.9 mRad

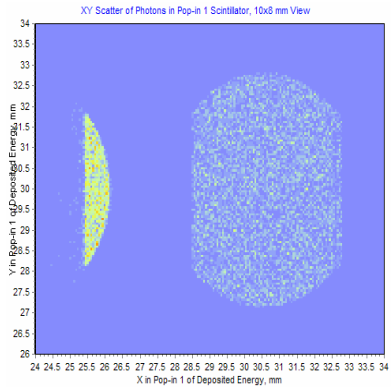
θ = 13.9 mRad

θ = 14.9 mRad

8 mm







Δy = -0 mm

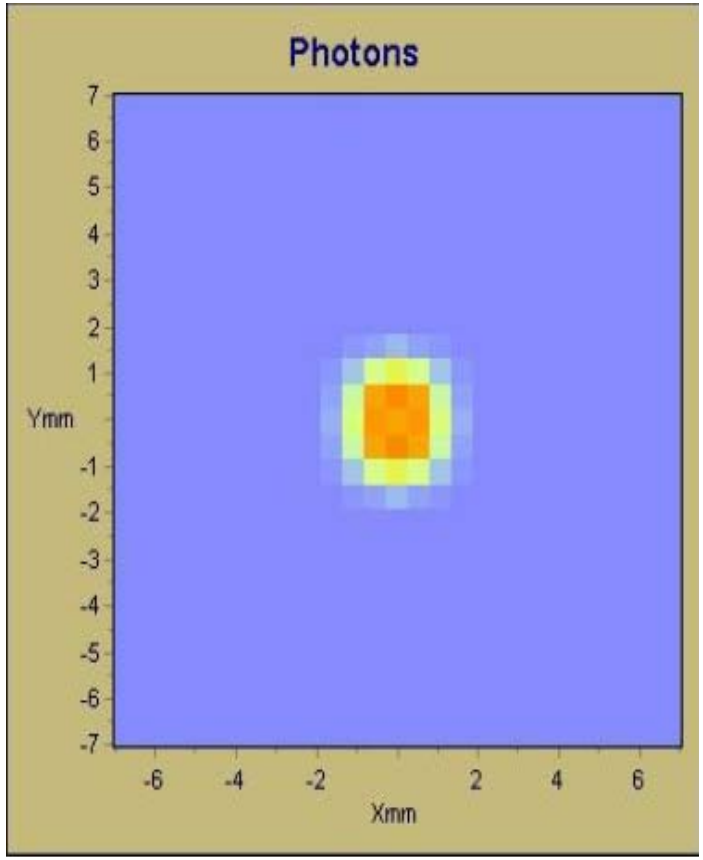
10 mm

FEE Commissioning at low energy (4.3 GeV) (Jul-Aug 09)

- Find beam center with 9th harmonic using K-monochromator
- With Soft X-FEL
  - Use Direct Imager, no apertures
    - "See" FEL at ~ 100 nJ
      - K measurement of undulators (if necessary)
    - Optimize FEL to 50 micro J
    - Align gas attenuator and gas detector
    - Continue optimizing FEL pulse energy and measure attenuated FEL with Direct Imager
  - Measure absolute pulse energy with thermal sensor
  - Calibrate Gas Detector with Thermal Sensor
  - Calibrate Direct Imager with Gas Detector

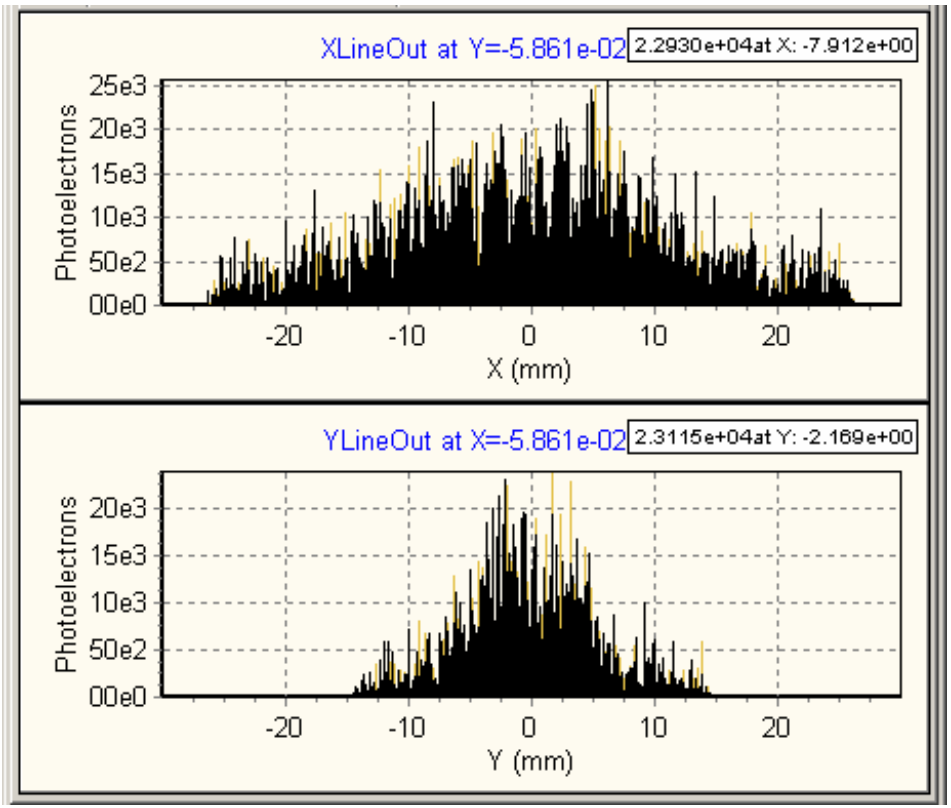
9th harmonic at 4.3 Gev through *K*-mono viewed by Direct Imager

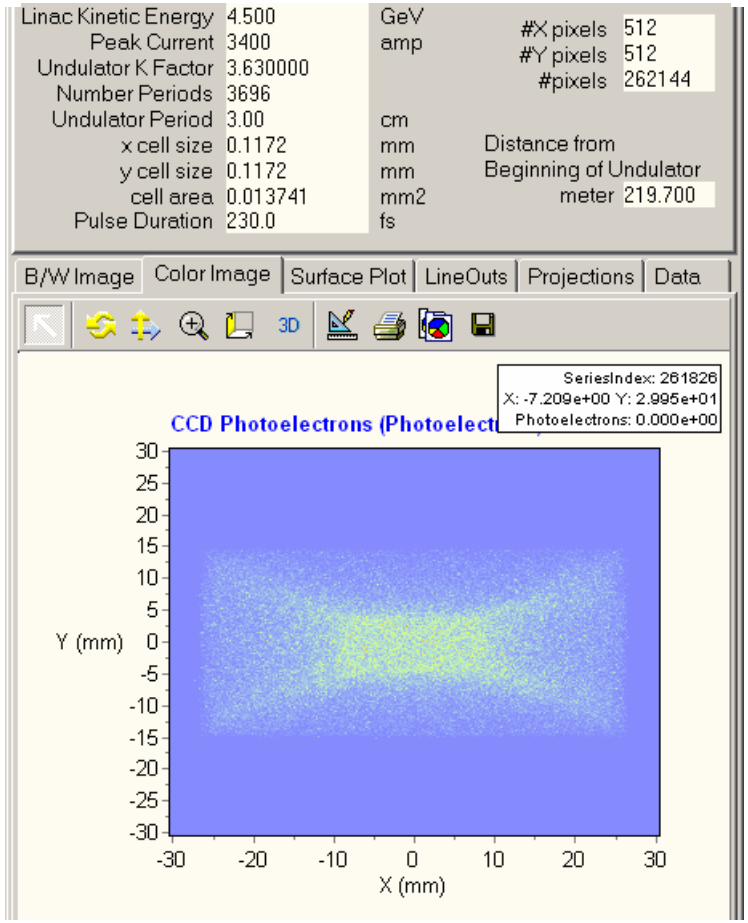
LCLS "Setting", i.e., fundamental hν (eV)	Harmonic	Observation hν (eV)
8172	1	8172
2724	3	
1634	5	
1167	7	
908	9	



Soft X-Ray Spontaneous all undulator segments, viewed by Direct Imager

Absorbed in 5 um YAG,





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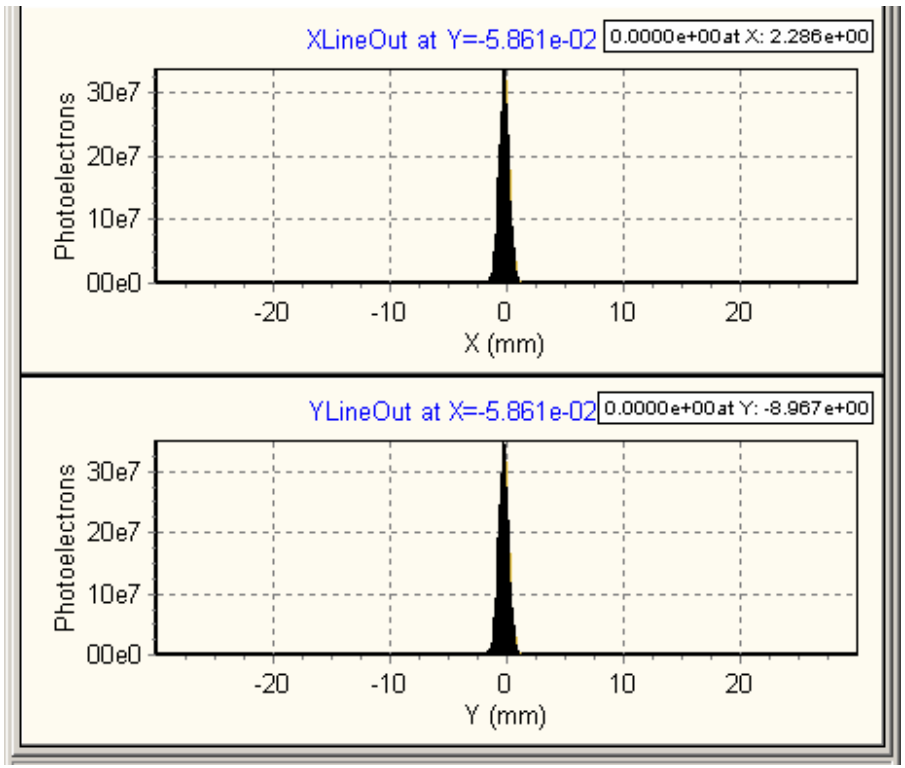
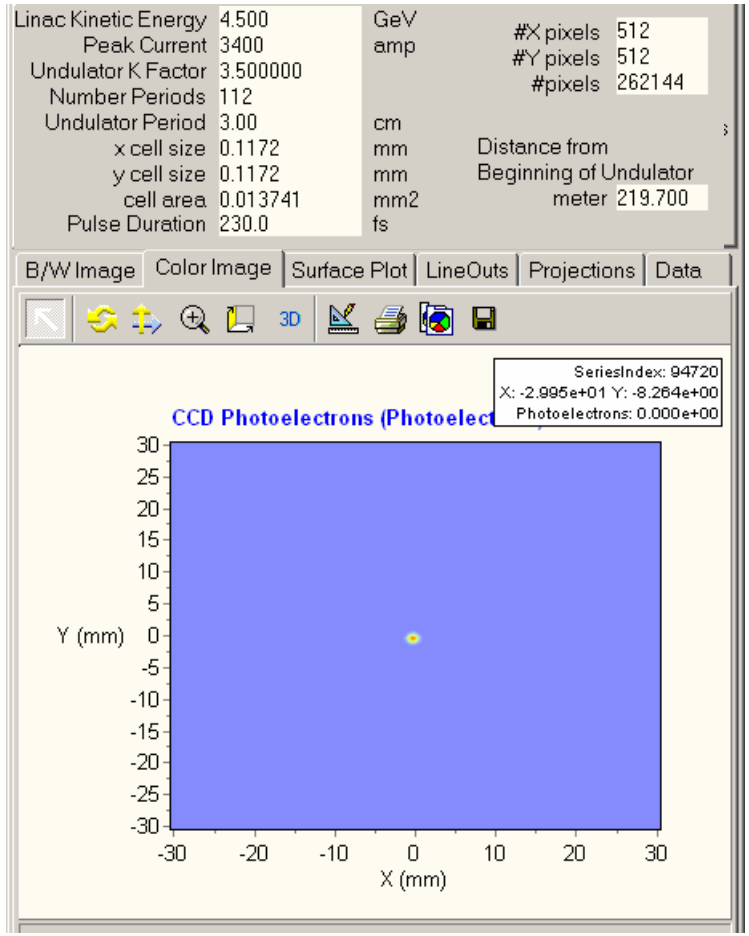
Soft X-Ray FEL signal in Direct Imager

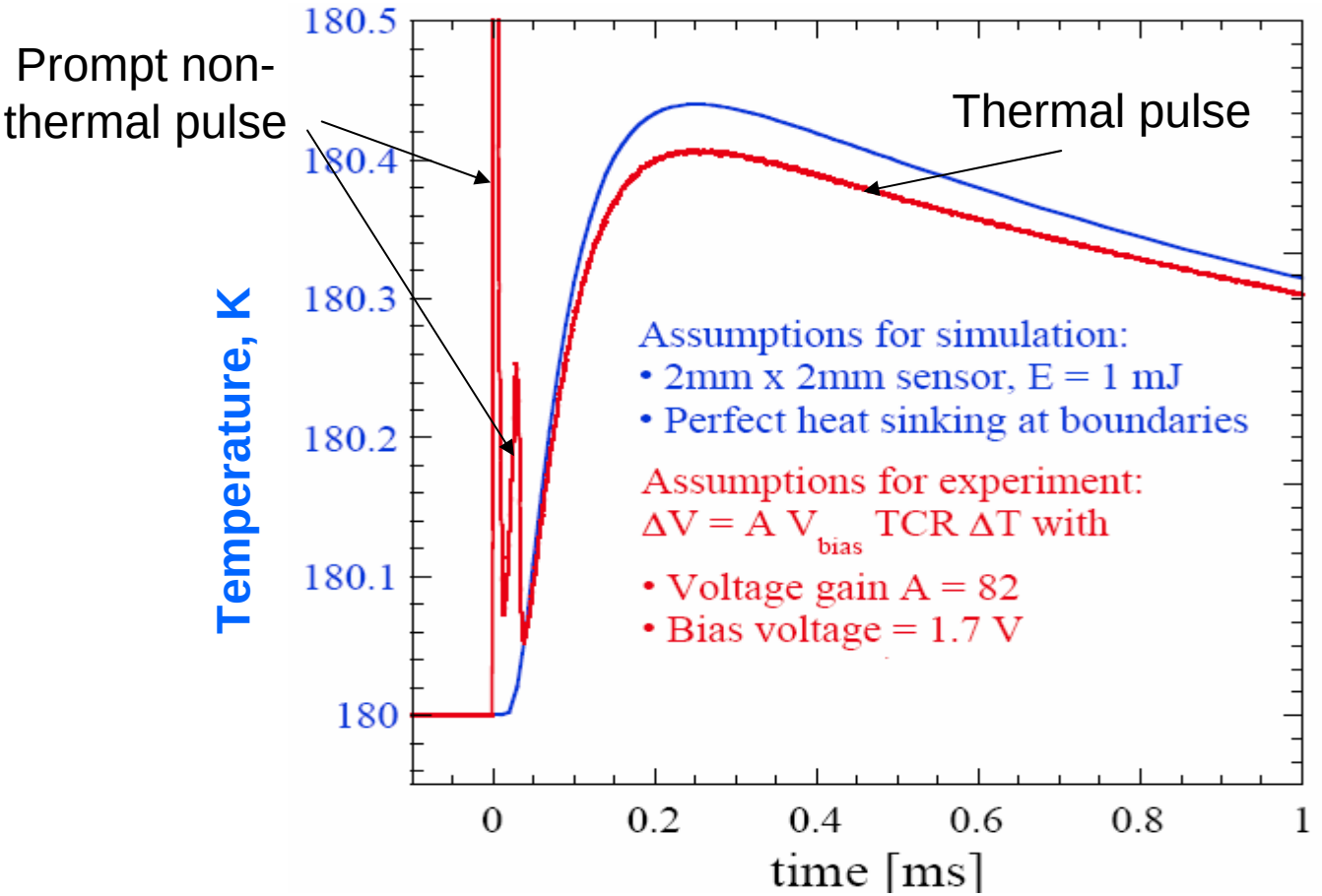
Absorbed in 5 um YAG,

Peak pixel has 160 photoelectrons / nJ of FEL

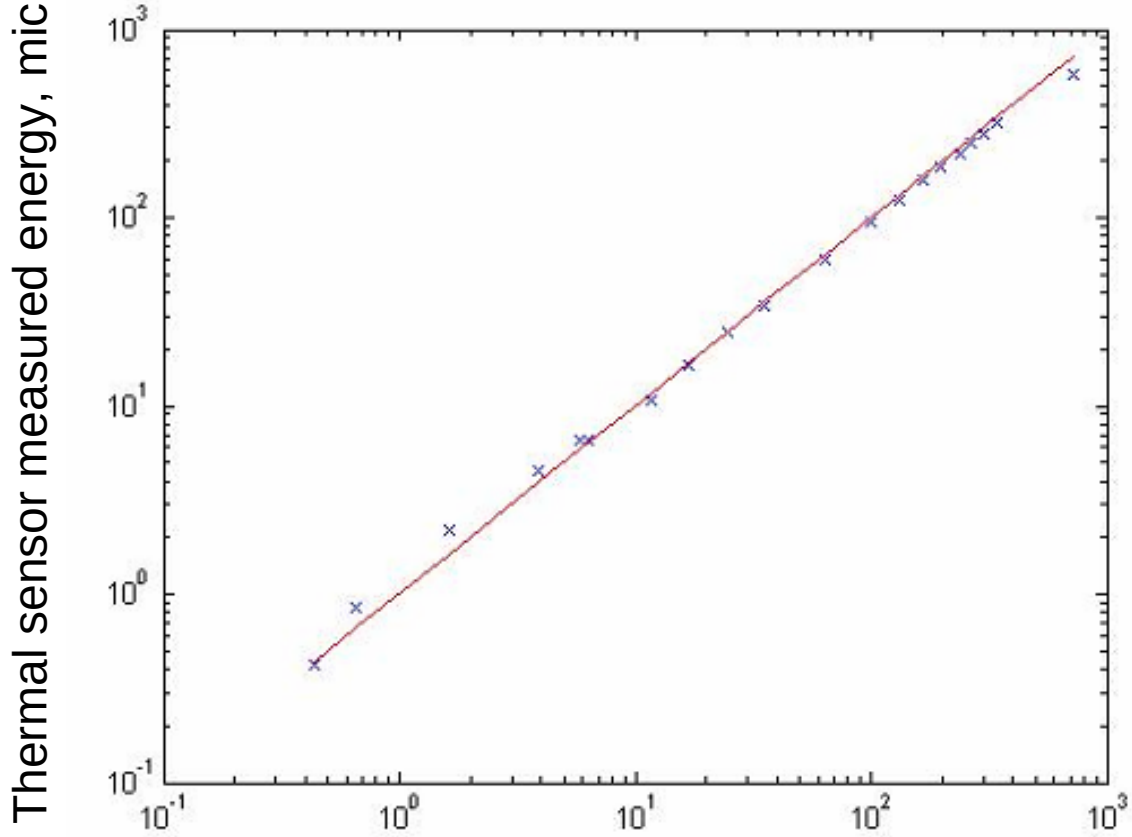




Thermal sensor, theory (blue) and experiment (red)



Thermal sensor measurements vs. calibration laser energy



High level control software

- Direct Imager
  - Image display, peak finder and centroid calculation, pulse energy measurement, stage motion, camera settings, focus, UV lamp and illuminator, cross calibration with Gas Detector (MATLAB/EPICS)
- Gas Detector
  - Waveform display, peak finder, prompt signal removal, cross calibration with Thermal Sensor, pressure control, pulse energy measurement, phototube HV (MATLAB/EPICS)
- Thermal sensor
  - Waveform display, sensor selection and positioning, peak finder, calibration with laser, prompt signal removal, R vs T measurement, pulse energy measurement (MATLAB/EPICS)

High level control software (cont.)

- *K*-monochromator
  - Waveform display, quad cell positioning, quad cell pulse position calibration, removal of prompt signal, total pulse energy measurement, crystal pitch angle, crystal placement (MATLAB/EPICS)
  - Acquire pulse energy, shift photon energy, plot undulator spectrum, move undulator, maximize slope (Paul Emma's group)
- Pop-in cameras
  - Image display, cross hair position extraction, camera control, scintillator positioning (EPICS)
- Slit
  - Aperture width, aperture center (EPICS)

High level control software (cont.)

- Gas and Solid Attenuator
  - Pressure, solid attenuator selection, stage control, apertures in/out control (EPICS)
- Others
  - Reticule positioning, SOMS and HOMS transverse position and angle, vacuum and isolation valve monitoring and control (EPICS)

Commissioning Manpower

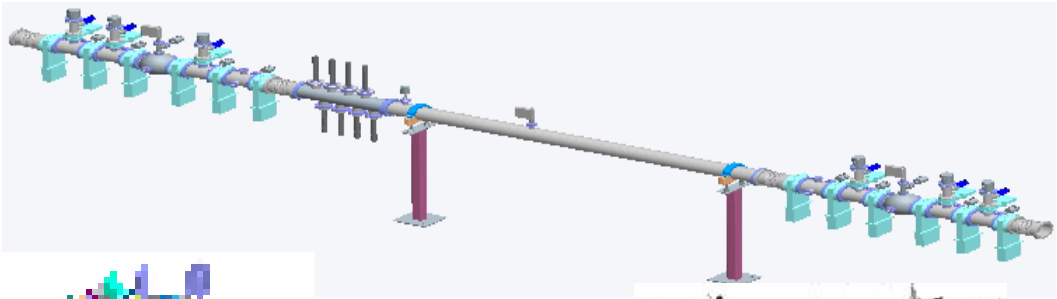
- PIs
  - R. Bionta (Direct Imager, Pop-ins)
  - S. Friedrich (Thermal Sensor)
  - S. Hau-Riege (Gas Detector)
  - S. Shen (Gas Attenuator)
  - T. McCarville (Mirrors)
  - E. Ables (Electronics)
  - P. Stefan (Mirrors, K-Monochromator)
- Software
  - S. Lewis (EPICS lead, vacuum, attenuator, and motion controls)
  - L. Ott (Direct Imager and *K*-mono MATLAB, EPICS, Simulations)
  - K. Fong (EPICS, Photon Monte-Carlo)
  - C. Gardner (Thermal sensor MATLAB)
  - S. Hau-Riege (Gas Detector MATLAB)

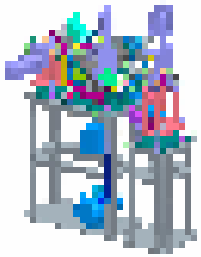
Handover to operation

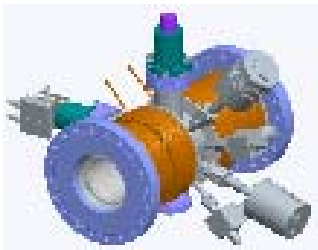
- Safety Reviews
  - All instruments have had formal reviews by LLNL
  - SLAC citizen committees reviews in Jun-Aug 08
  - Readiness review for FEE + NEH in Mar-Apr 09
- Documentation
  - As built drawings
  - ESDs
  - IWS safety plans and seismic analysis
- Training
  - Peter Stefan working closely with LLNL staff for all instruments
  - Controls developed by Steve Lewis according to Guinther Haller's guidance
  - Other SLAC personnel will be trained during commissioning

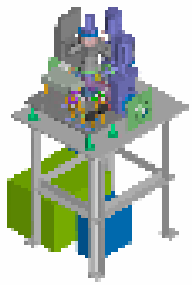
FEE Diagnostic Hardware Status

- Fixed Mask / Slit
  - In house, Integrated testing
- Attenuator
  - Under assembly
- Gas Detectors
  - In house/integrating
- Thermal Sensor
  - Vessel on order
  - Sensors in fabrication
- Direct imager
  - Vessel on order
  - Cameras, scintillators, filters in house
- ***K* monochromator in final design**
- Pop-in Monitors ready for PDR
- Controls
  - 4 of 5 FY08 FEE racks complete
  - FEE Vacuum Rack complete
  - 98% of ***all*** other controls h/w received









Summary

- FEE diagnostics will be ready for installation
  - November 2008: Fixed Mask, Slit, Gas Detector, Attenuators, Direct Imager, Thermal Sensor
  - January 2009: *K* monochromator, SOMS/HOMS mirror system and Pop-ins
- Initial checkout of FEE instruments without beam in Mar-May 09
  - Controls, motion, vacuum, pressure, calibration laser
- Initial commissioning and alignment of FEE instruments with high-energy spontaneous in May-Jun 09
  - Direct imager, Attenuator, Gas Detector, Calorimeter, *K*-Monochromator
- Mirrors will be aligned with spontaneous in Jun-Jul 09
  - Using Pop-in cameras
- Low energy FEL will be commissioned in Jul-Aug 09
  - Direct Imager will be main diagnostic for finding FEL