XTOD Layout and Diagnostic Systems

Facility Advisory Committee
Meeting

October 12-13, 2004

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

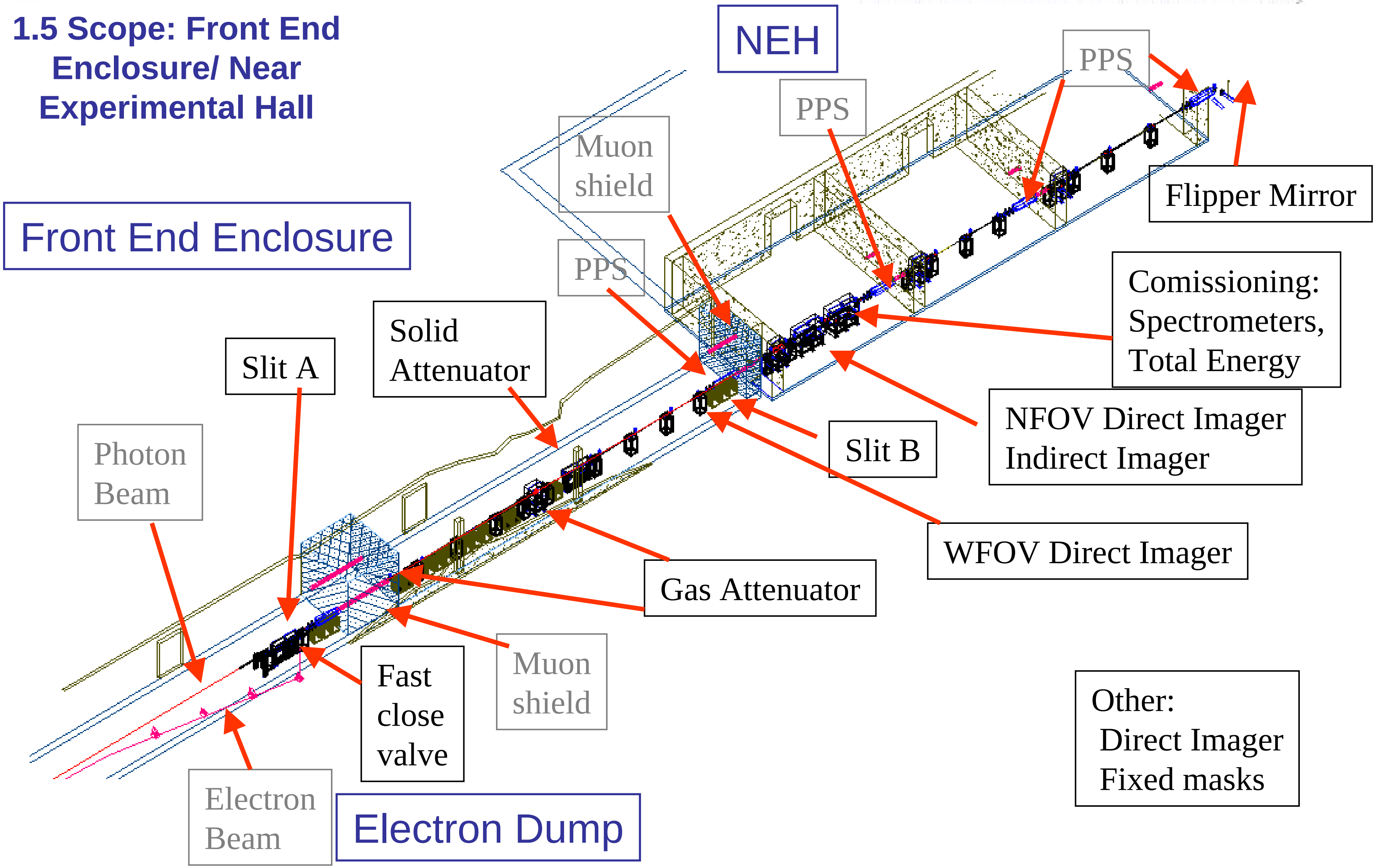
Richard M. Bionta
bionta1@llnl.gov

Outline

- Scope of WBS 1.5
- Organization
- XTOD Physics Requirements & Risk Mitigation
- Instrumentation Status

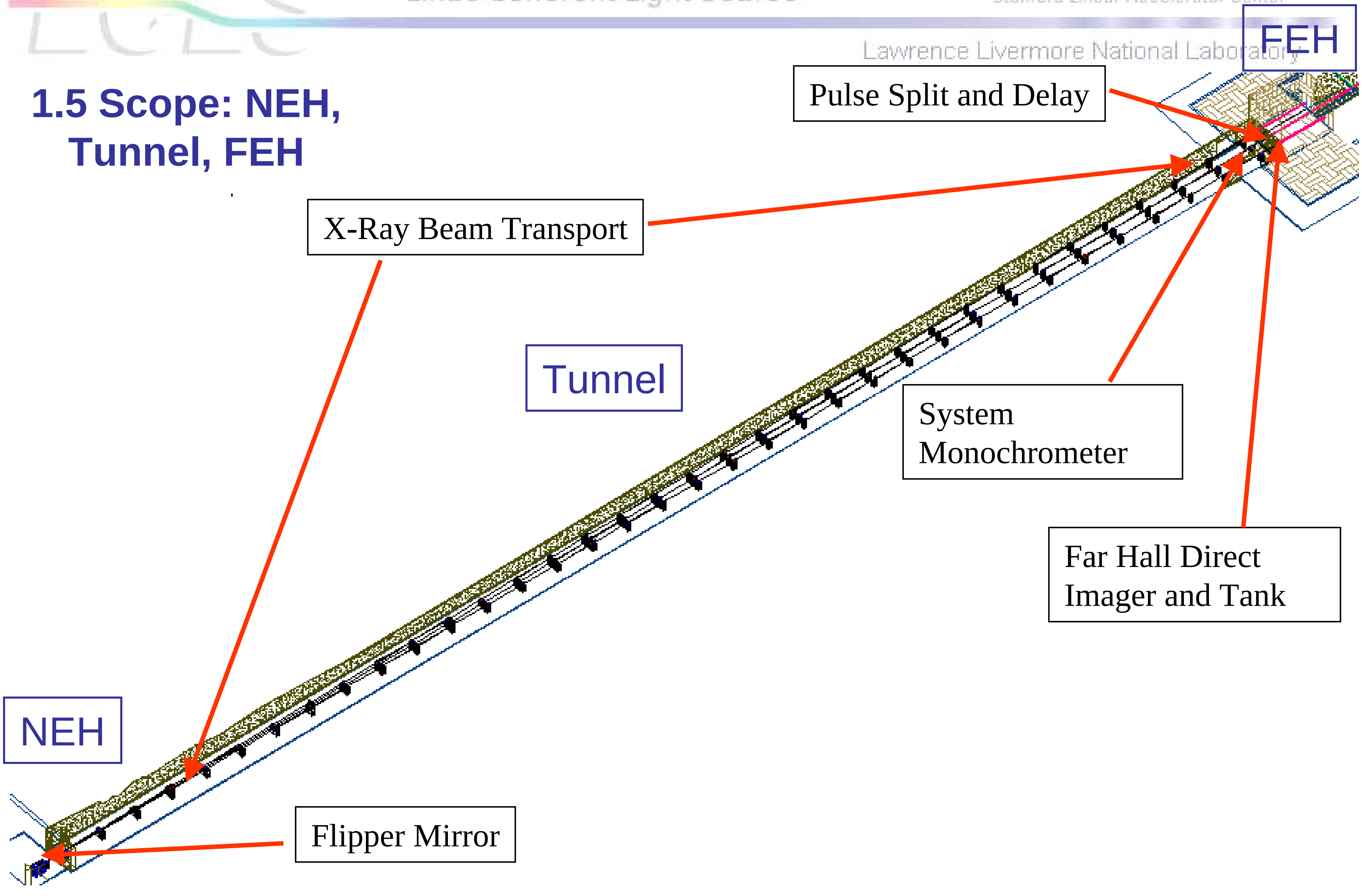
Richard M. Bionta
bionta1@llnl.gov

1.5 Scope: Front End Enclosure/ Near Experimental Hall



Richard M. Bionta
bionta1@llnl.gov

1.5 Scope: NEH, Tunnel, FEH



XTOD Staff-up complete for FY05

R. Bionta
LLNL LCLS Project Leader
D. McMahon
XTOD Project Engineer

- Rodney Victorine – Resource Manager
- Jolyn Scholes – Resource Analyst
- J. McNamara – Admin.
- M. Eberstein, G. Otani – Procurement
- R. Beale – Hazards Control

<u>EE</u>
E. Ables

<u>ME</u>
P. Duffy
M. Mckernan
S. Shen
J. Trent

<u>Comp</u>
K. Fong
S. Lewis
L. Ott

<u>Physics</u>
S. Friedrich
S. Hau-Reige
M. Pivovaroff
D. Ryutov

<u>DNT</u>
R. London

<u>UC Davis</u>
H. Baldis

Remainder of FY05 P3 labor "loosely" matrixed, i.e L. Li - thermal analysis, Bajt, multilayers, shops, finance…

XTOD Physics Requirements: Optics and Transport

- Beam Transport
  - $<10^{-5}$ T vacuum
  - >10 year pump life
  - Missing - Radiation hardness
- Xray Optics
  - Attenuate: by 10^{-4} to 1%
  - Slits: 1 μm adjustable precision to 8 x beam size
  - Order-Sorting Mirror: pick off 1st order, reflect $< 10^{-5}$ 3rd order - dropped during budget reconciliation
  - "Flipper Mirror" - 3 reflections, >80% reflective from 0.8 to 18 keV, jitter < 10% beam size
  - Far-Hall Monochrometer:
    - XTAL: 2-25 keV, resolution $> 10^4$
    - Grating: 0.5 to 2 keV, resolution $> 10^3$
  - Pulse-Split delay: 8-18 keV, 0-200ps delay, 50 fs Δt
  - Controls: EPICS

Richard M. Bionta
bionta1@llnl.gov

XTOD Physics Requirements: Diagnostics

- PRD Required measurements
  - Centroid position to 5% of beam size
  - Transverse dimensions to 10% of beam size
  - Divergence to 10% of divergence
  - Beam energy to 0.02% of beam energy
  - Energy spread to 20% of energy spread

Richard M. Bionta
bionta1@llnl.gov

Other XTOD Requirements

- Commissioning
  - Measurements to confirm Spontaneous flux levels at first few harmonics
  - Measurements down to single undulator spontaneous flux levels
  - Instrumentation to "find" and measure the FEL when it is at very low power
  - Instrumentation to measure FEL gain vs. z studies with roll-away undulators or electromagnetic trips

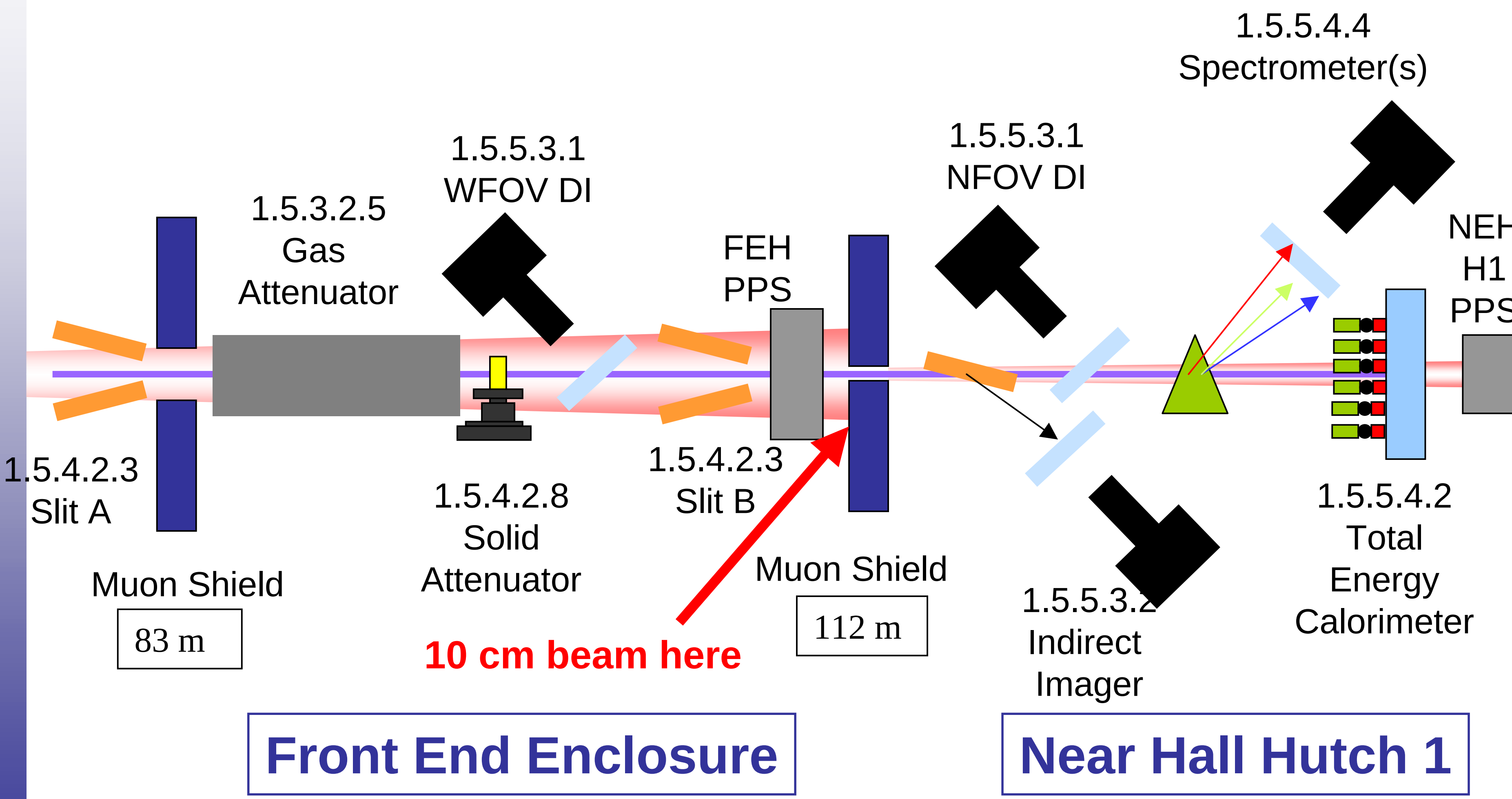
Richard M. Bionta
bionta1@llnl.gov

Spontaneous Spectrometer Requirements

- Variable slit
  - 4 independent jaws -range +- 6 mm from center, 0.01 mm repeatability
  - within 10 meters upstream of spectrometer
- Camera
  - need to see first harmonic through variable slits as we close down the slits
  - need to spatially resolve 0.03 mm vertically, 0.06 mm horizontal
  - should be mechanical stable at 0.1 mm for hours
- Spectrometer
  - Covers energy range 8000 -8500 eV
  - Bin width ~1-10 eV
  - Efficiency >1%
  - dynamic range:10^6 - 10^8 photons incident per pulse
  - readout every shot up to 120 Hz

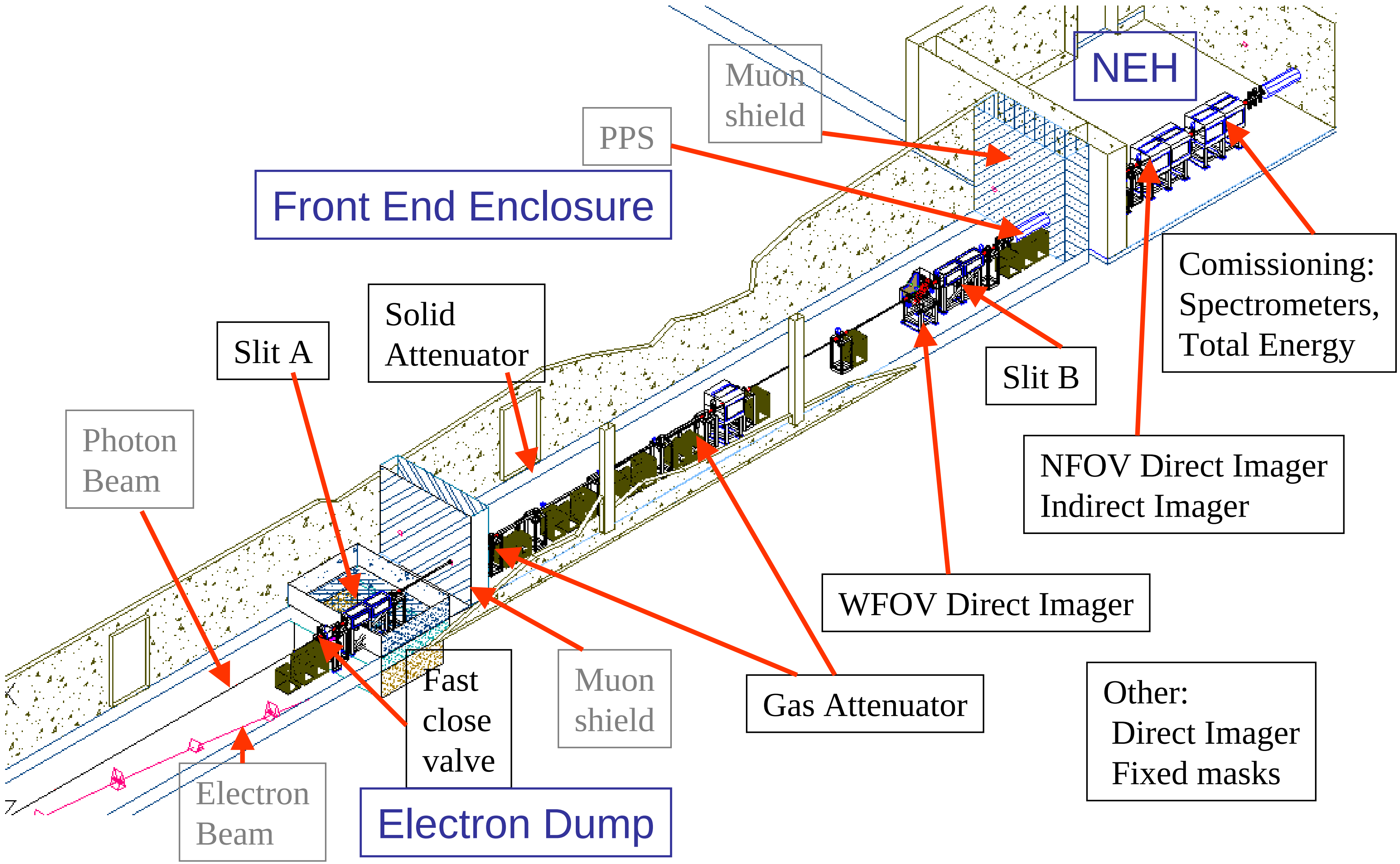
Richard M. Bionta
bionta1@llnl.gov

XTOD Baseline Front End

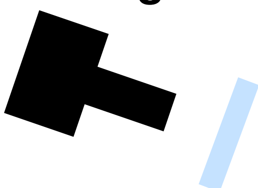
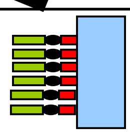
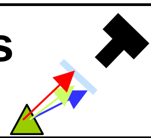


Richard M. Bionta
bionta1@llnl.gov

XTOD Baseline Front-End Layout



Commissioning instrumentation is redundant and overlapping

Instrument	Purpose	Adjustment	Calibration and Physics risks
Direct Imager 	SP, look for FEL, measure FEL Energy, shape, centroid	ND filter, Attenuators	Scintillator linearity, Attenuator linearity and background
Indirect Imager 	Measure FEL, crude spectral imaging of SP and FEL harmonics	Mirror Angle	Mirror reflectivity, damage
Total Energy 	FEL Energy	Attenuators	Energy to Heat, damage
Spectrometers 	FEL, SP spectra	Attenuators	*

Richard M. Bionta
bionta1@llnl.gov

Risk registry documents risks

- 1.5.001 & 002 Attenuator Performance
  - Cross check with total E and Indirect Imager
- 1.5.003 Backgrounds and access
  - Initially locate sensitive cameras, spectrometers, .. In NEH H1
- 1.5.004 Limiting Apertures
  - Locate a WFOV DI in FEE. Allow 10 cm beam in FEE.
- 1.5.007 Beam parameters and high flux physics uncertainties
  - Add redundancy and flexibility. Have codes ready. Measure simple things first i.e. spontaneous levels
- 1.5.005 Design Immaturity
  - Design Front-end first
- 1.5.006 Late changes
  - Stick to P3

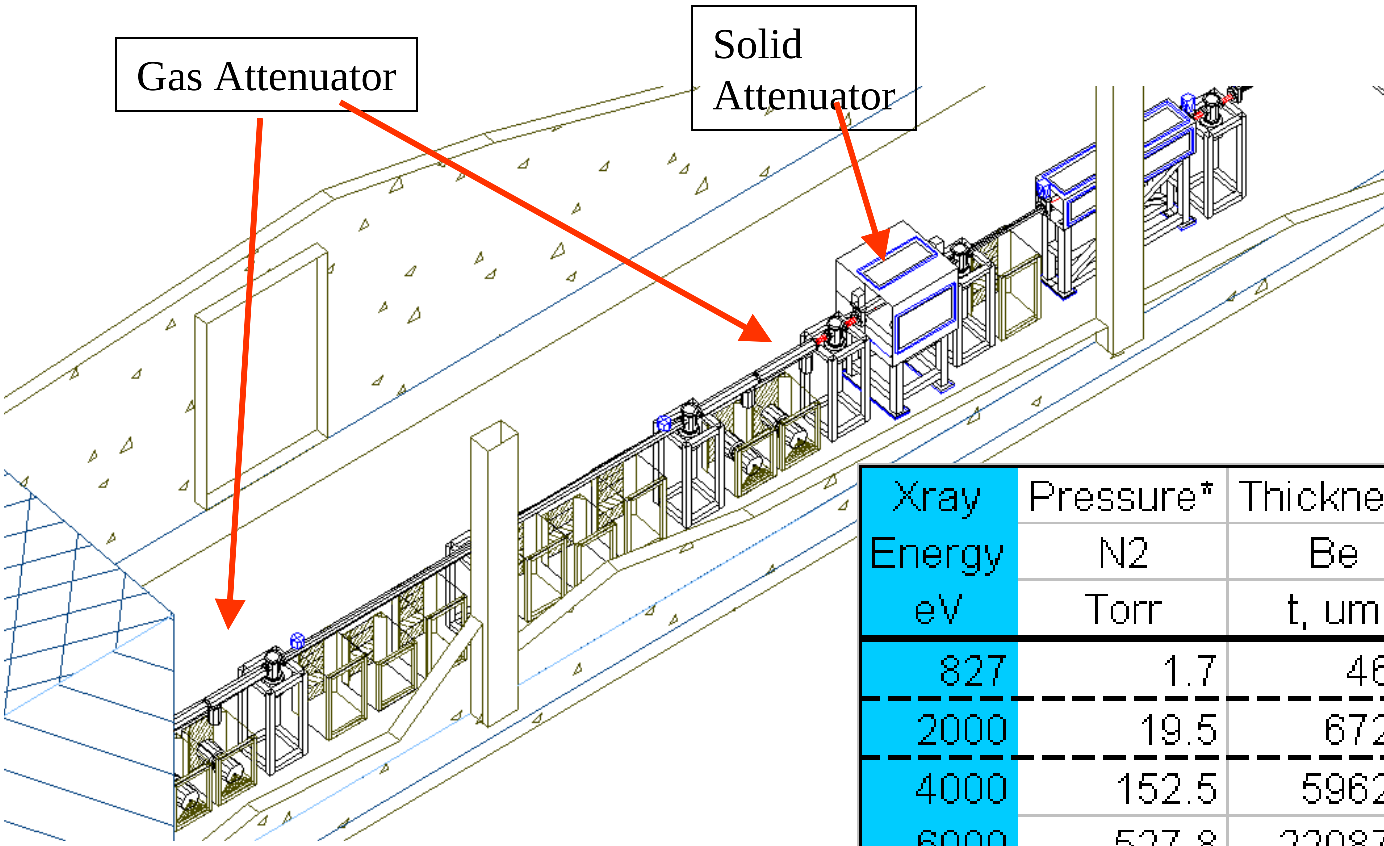
Richard M. Bionta
bionta1@llnl.gov

Oct. 2004 FAC XTOD Findings

- X-ray beamline controls not defined
- Details of designs are sparse, User workshops should be aimed at collecting more detail.
- There is not enough effort going into the shot-by-shot beam diagnostics
- There is not enough effort going into optics stability
- Concentrate on LCLS-specific problems such as shot-by-shot diagnostics, data flow, feedback control, preservation and measurement of coherence
- The detector advisory committee should coordinate the effort of LCLS and MIE
- Identification and communication of critical issues to LCLS experimenters should be a priority
- Do not fund detector efforts unless resources are sufficient to produce a useful end result

Richard M. Bionta
bionta1@llnl.gov

Gas and Solids Attenuator Conceptual Design



Xray Energy eV	Pressure* N2 Torr	Thickness Be t, um
827	1.7	46.5
2000	19.5	672.0
4000	152.5	5962.5
6000	527.8	22087.8
8000	1292.6	56579.1

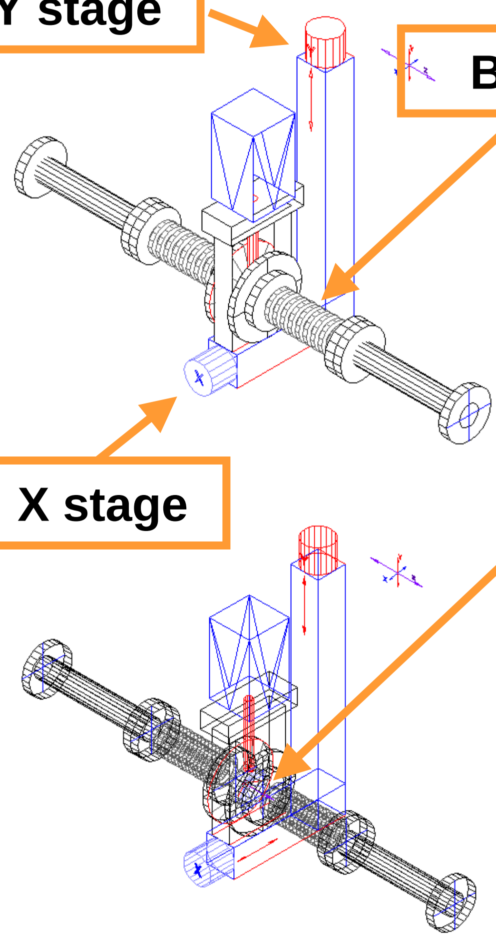
Use Gas

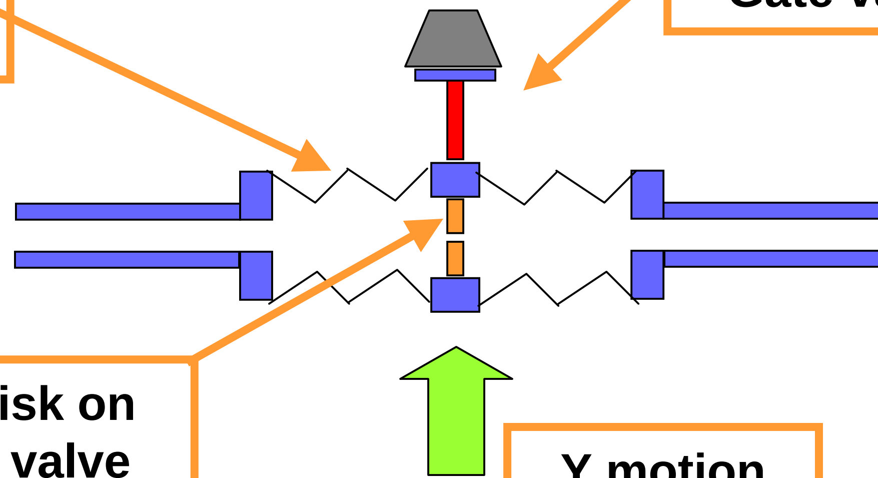
Use Solids

* For a transmission of 10^{-4}

Richard M. Bionta
bionta1@llnl.gov

Bellows allow transverse positioning of opening in window





Be disk on gate valve transparent to high energy spontaneous, allows alignment of hole using WFOVDI camera in FEE. Gate valve removes window when gas attenuator not in use.

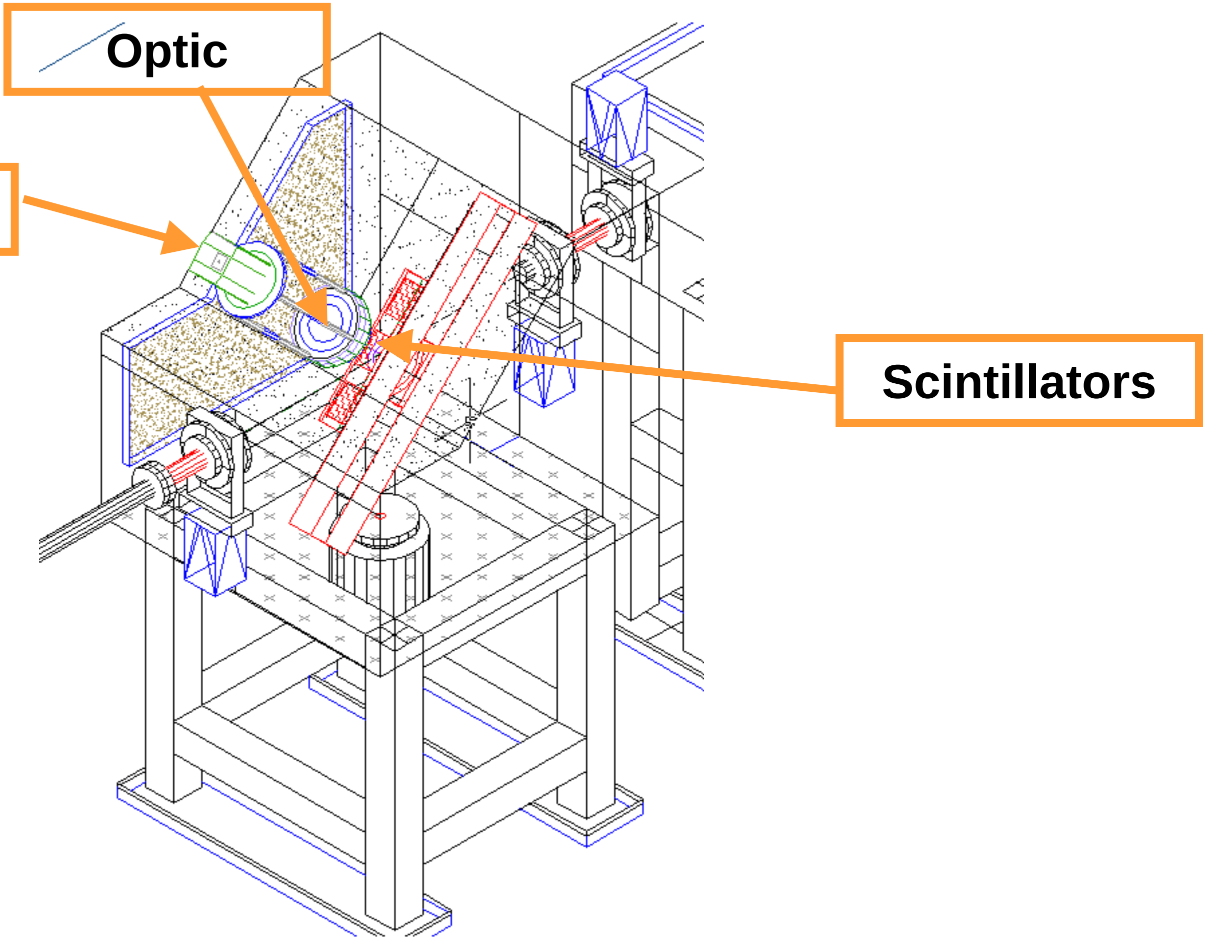
Richard M. Bionta
bionta1@llnl.gov

Attenuator Status

- Gas Attenuator
  - Stewart Shen & Co. on board
  - On schedule for prototype (1/2) in Oct 2005
  - Still discussing add-on florescence or ionization detection for shot-to-shot monitoring of FEL
  - Decision to add X-ray attenuator monitor (Cu L) awaits prototype performance tests
- Solid Attenuator
  - To be designed in late FY06
  - Backgrounds must be calculated (Alberto Fasso)

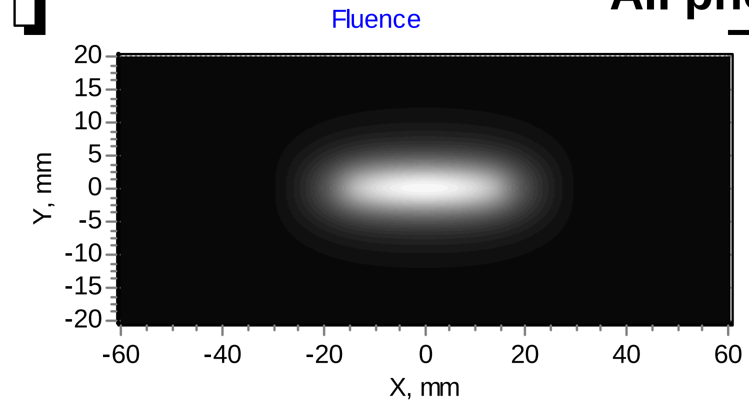
Richard M. Bionta
bionta1@llnl.gov

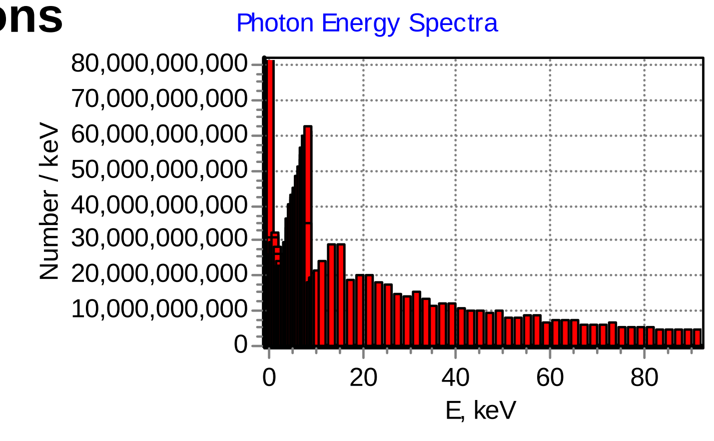
Wide Field of View Direct Imager



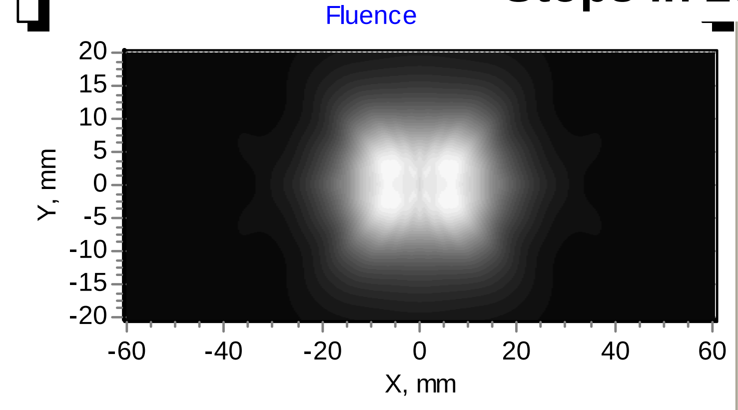
Calculating WFOV DI Response to 14.5 GeV Spontaneous Radiation…

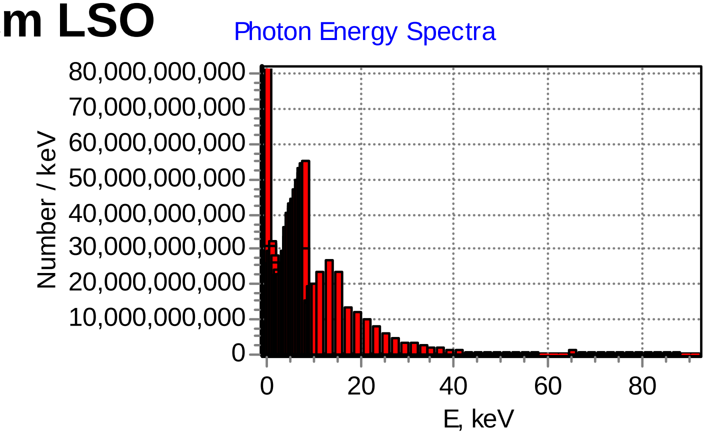
All photons





Stops in 25 μm LSO





Richard M. Bionta
bionta1@llnl.gov

14.5 GeV Spontaneous Direct Imager Signal

All photons

	Photons		Energy	
Total	1.661E+12		18.178	mJ
Peak	7.765E+07		0.002	mJ
Peak Density	2.588E+11	/cm2	5.728E-03	J/cm2

Stops in 25 μm LSO

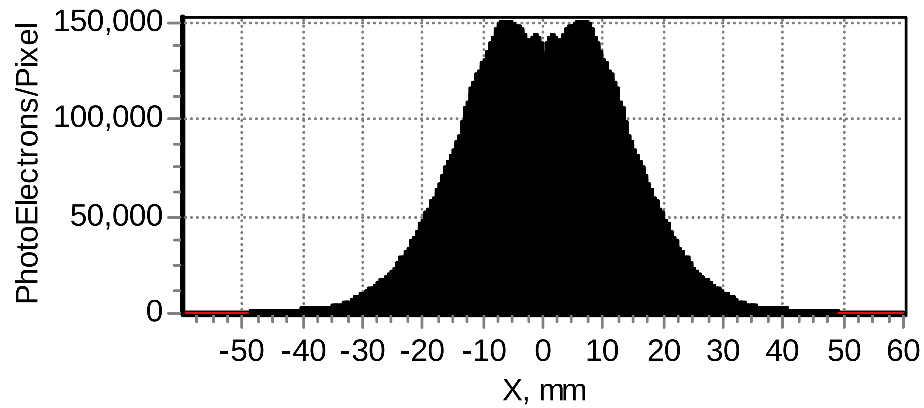
	Photons		Energy	
Total	6.746E+11		1.576	mJ
Peak	1.688E+07		0.000	mJ
Peak Density	5.626E+10	/cm2	1.827E-04	J/cm2

CCD photoelectron levels < 150K e^-

Full well (16 bit) 327K e^- so this is ½ scale on CCD readout

(X-Ray resolution 300 x 100 μm)

Photoelectrons/Pixel

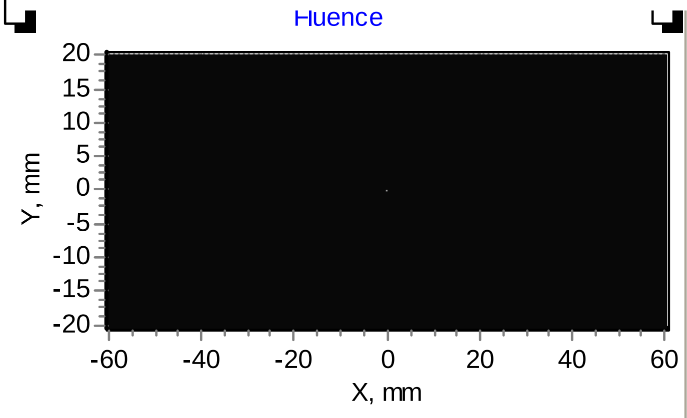


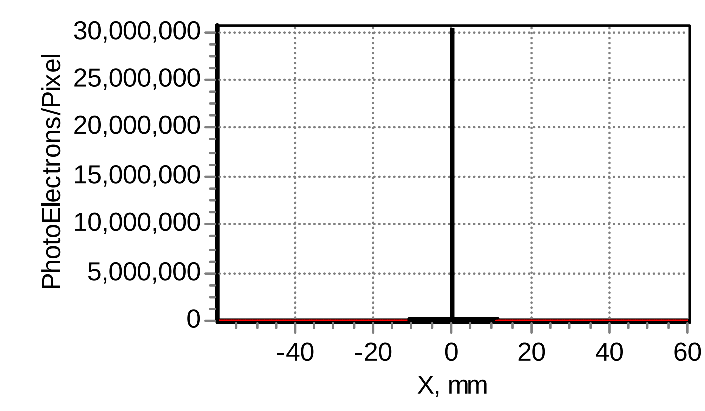
Response to faint FEL

(X-Ray resolution
300 x 100 μm)

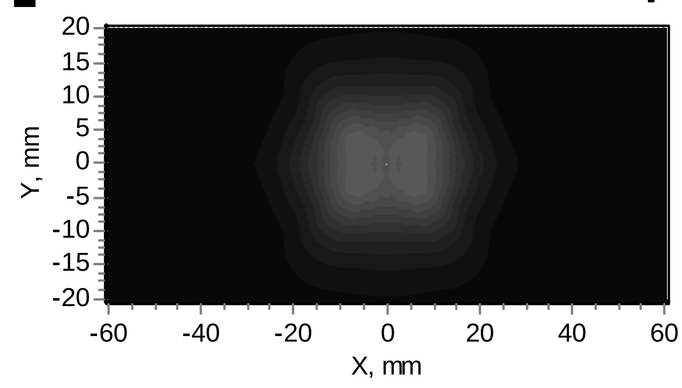
14.5 GeV

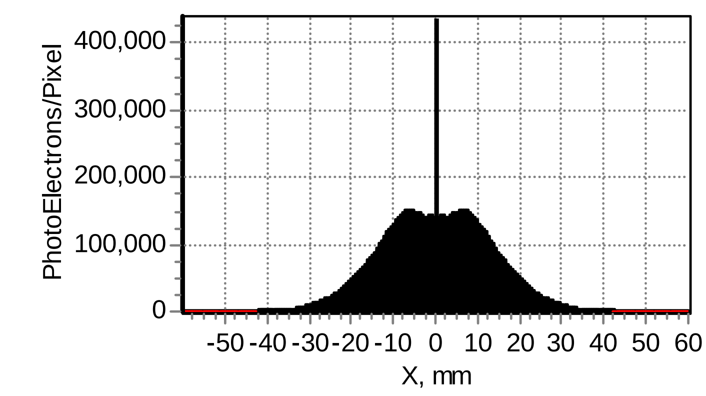
1% FEL + Spontaneous directly into 25 mm LSO





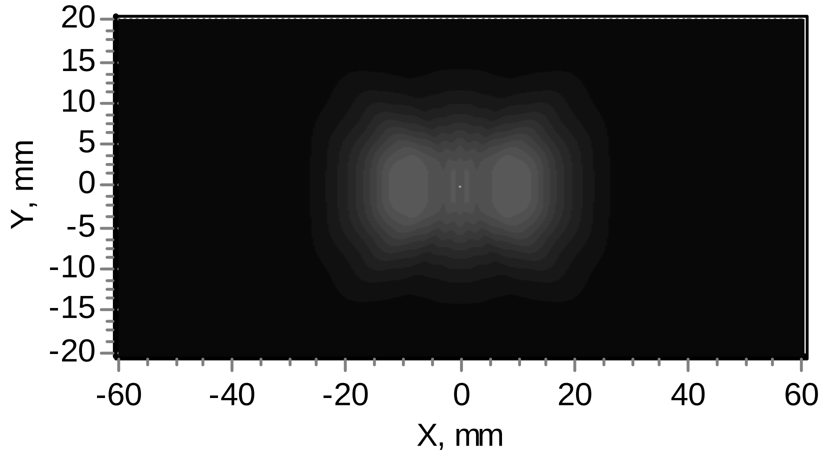
0.01% FEL + Spontaneous into 25 mm LSO

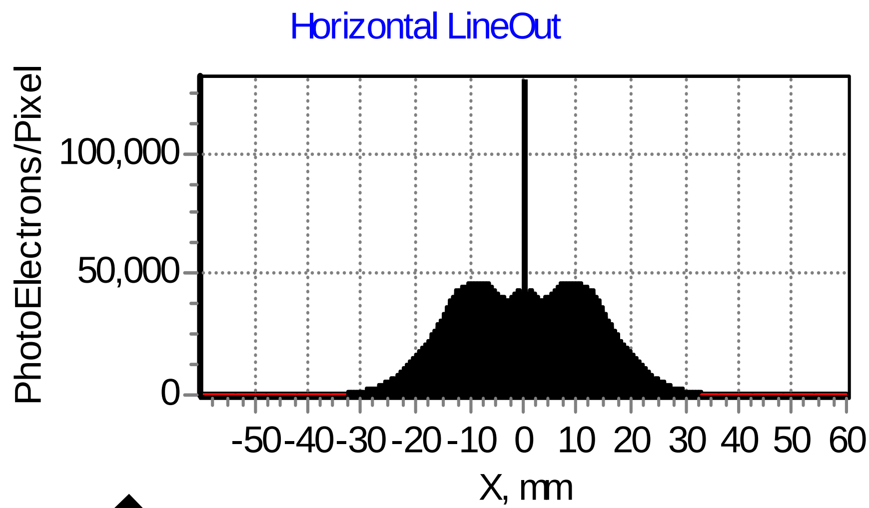


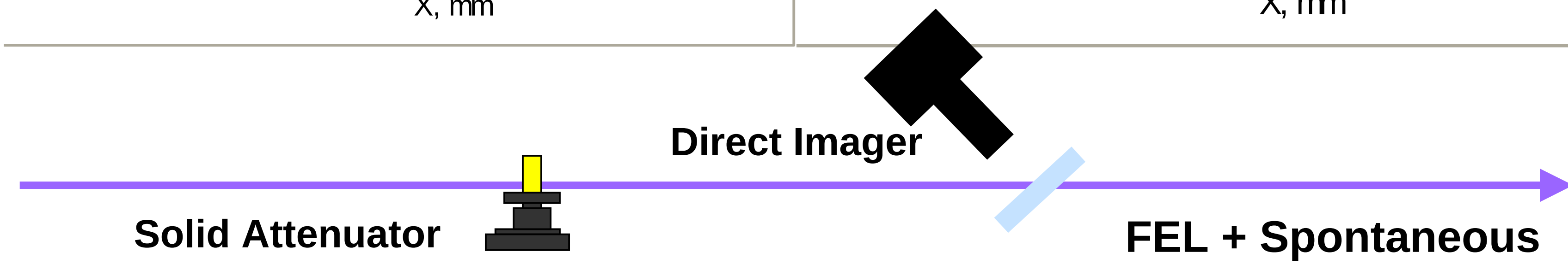


WFOVDI Imaging Full Power FEL through Attenuator

CCD Response, photoelectrons/pixel



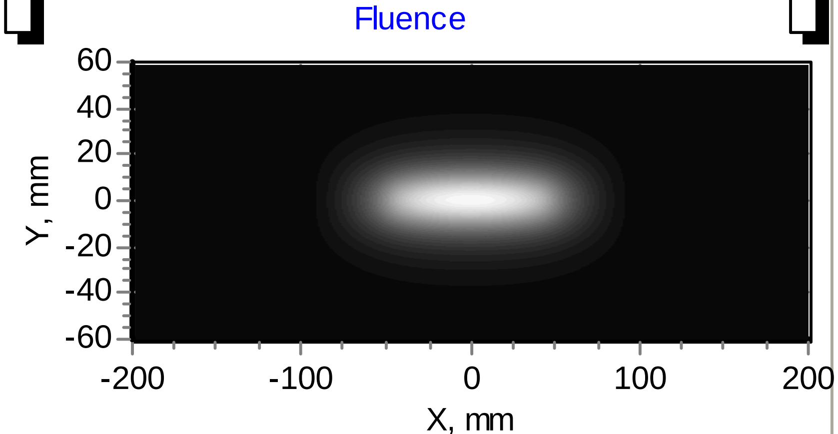




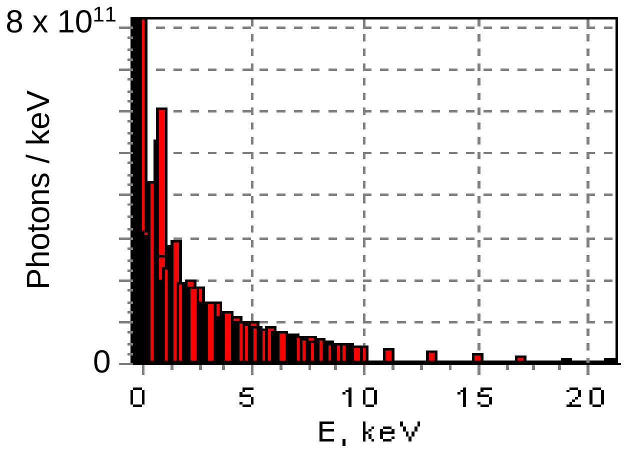
Direct imager exposed to full 8 keV FEL + Spontaneous through solid attenuator (16.8 mm B4C)

4.5 GeV Spontaneous

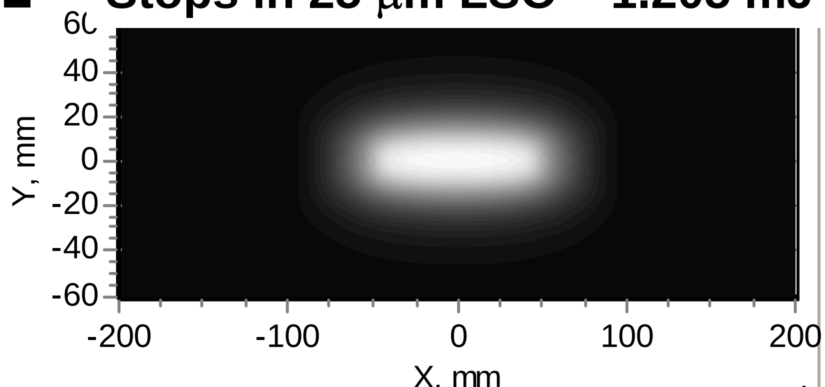
All photons 1.852 mJ



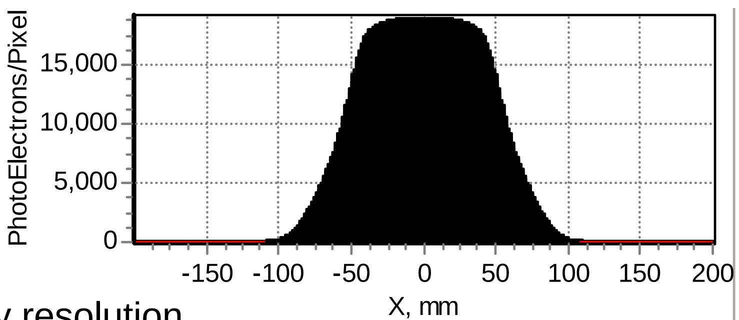
4.5 GeV Photon Spectra



Stops in 25 μm LSO 1.205 mJ



Direct Imager Photoelectrons

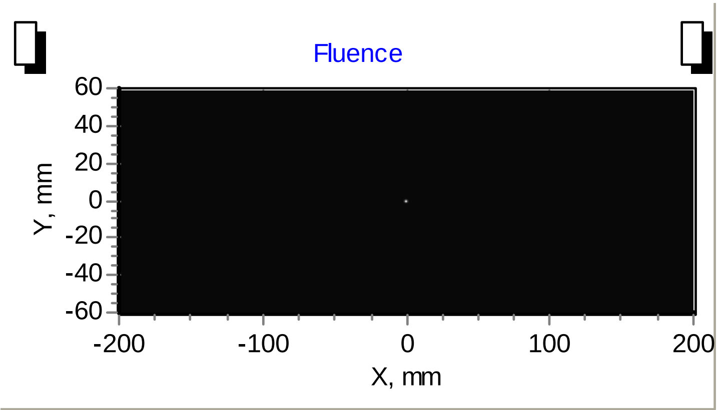


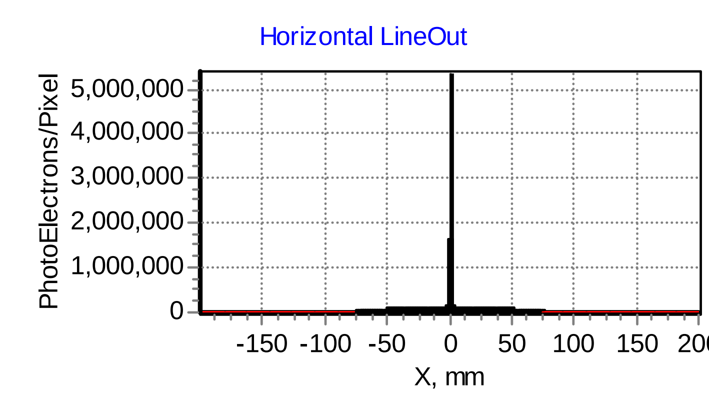
(X-Ray resolution 1000 x 300 μm)

4.5 GeV Spontaneous + ε x FEL

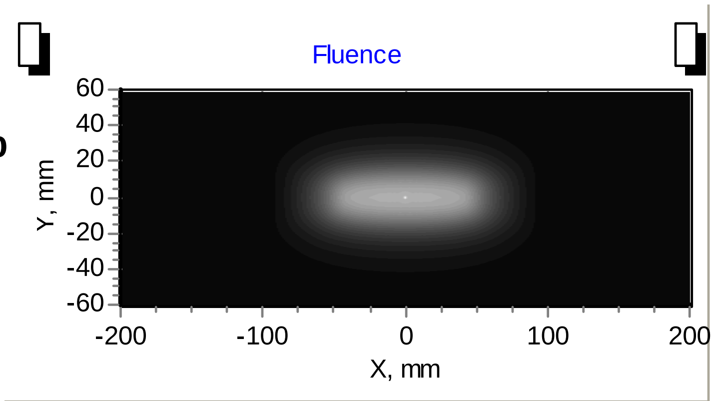
Direct Imager Image | **Direct Imager Photoelectrons**

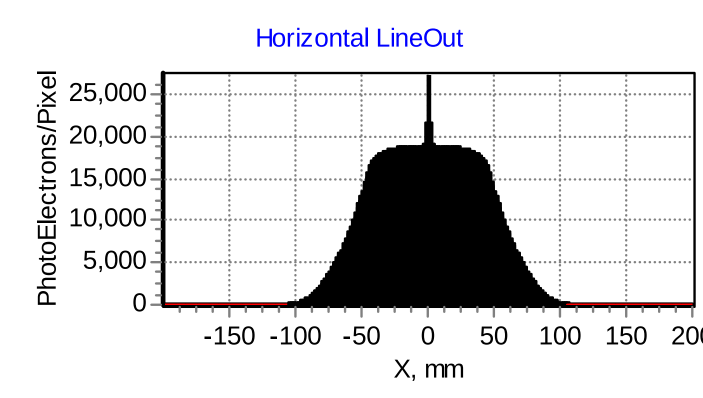
1 % FEL





0.01 % FEL





(X-Ray resolution
1000 x 300 μm)

High Speed Imaging Cameras

Vision Research

model	Image size	max frame rate	pixel resolution
V5.1	1024X1024	500	8 bits
V7.1	800X600	2000	12 bits
V9.0	1632X1200	500	10 bits

Basler

CAMERA Link

A402K	912X912*	120	10 bits
A403K	1280X1280*	120	10 bits
A504K	1280X1024	500	8 of 10 bits

Photometrics

512B	512X512	29	16 bits
512B	64X64*	155	16 bits
512F	512X512	29	16 bits
512F	64X64*	155	16 bits

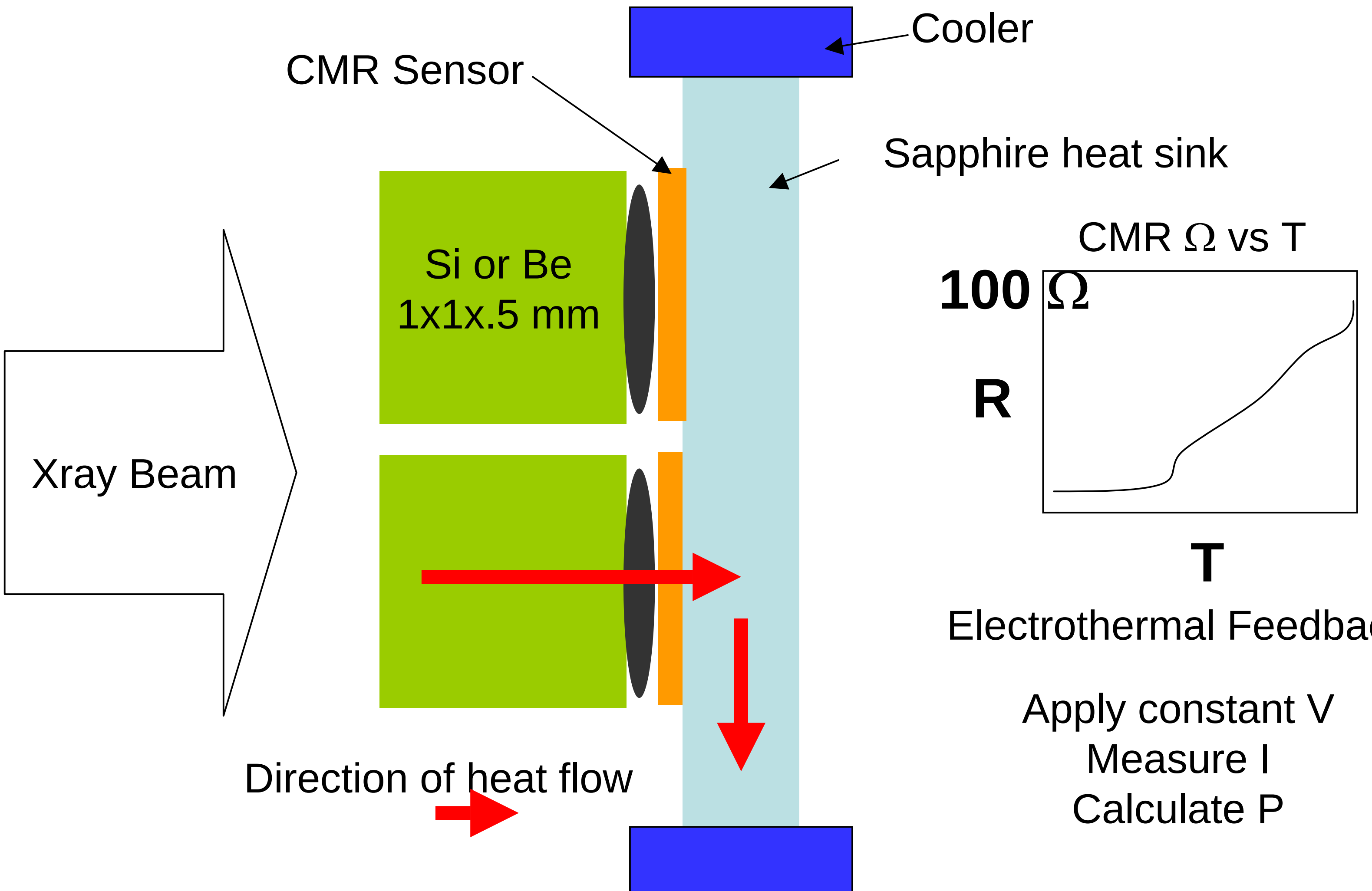
Richard M. Bionta
bionta1@llnl.gov

WFOVDI Schedule

- Simulations
  - Select Scintillators & Camera 5/05
  - Specify Optic 6/05
- Engineering
  - Select WFOV Optic 6/05
  - Design WFOVDI and Prototype 8/05
  - Purchace / Fab Prototype 9/05

Richard M. Bionta
bionta1@llnl.gov

Total Energy Calorimeter Concept

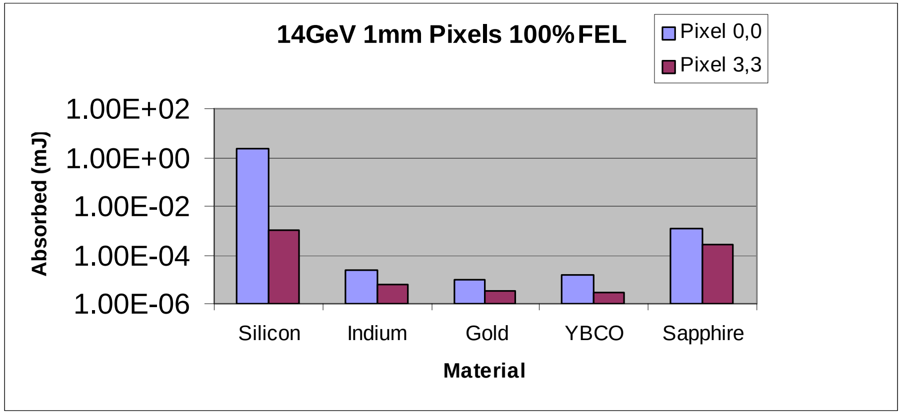


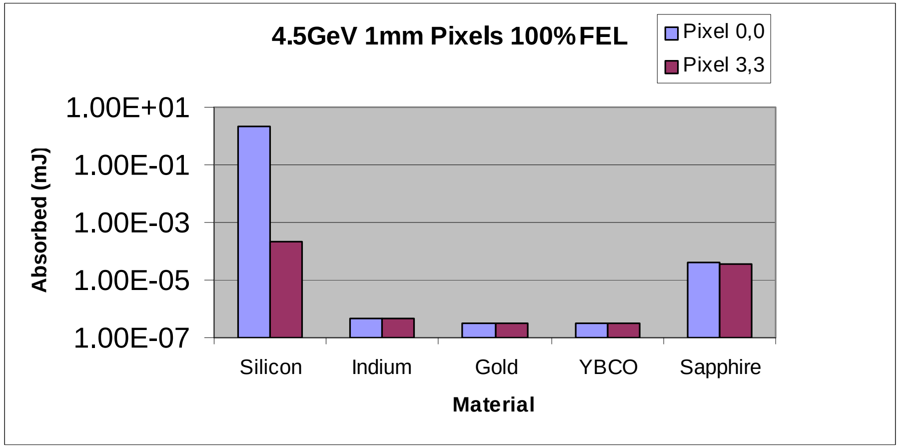
Electrothermal Feedback:

Apply constant V
Measure I
Calculate P

Richard M. Bionta
bionta1@llnl.gov

Energy deposition in each layer

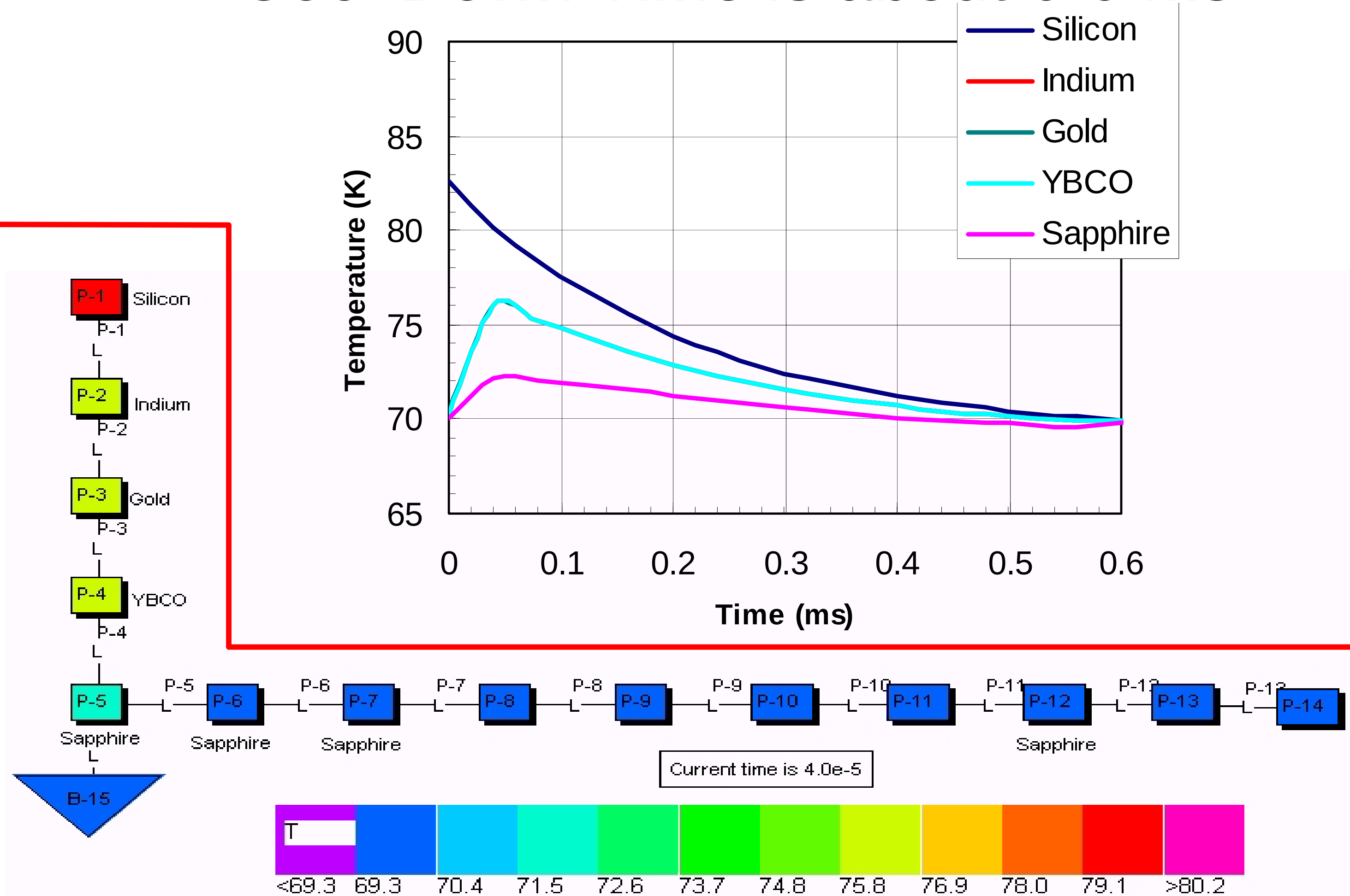




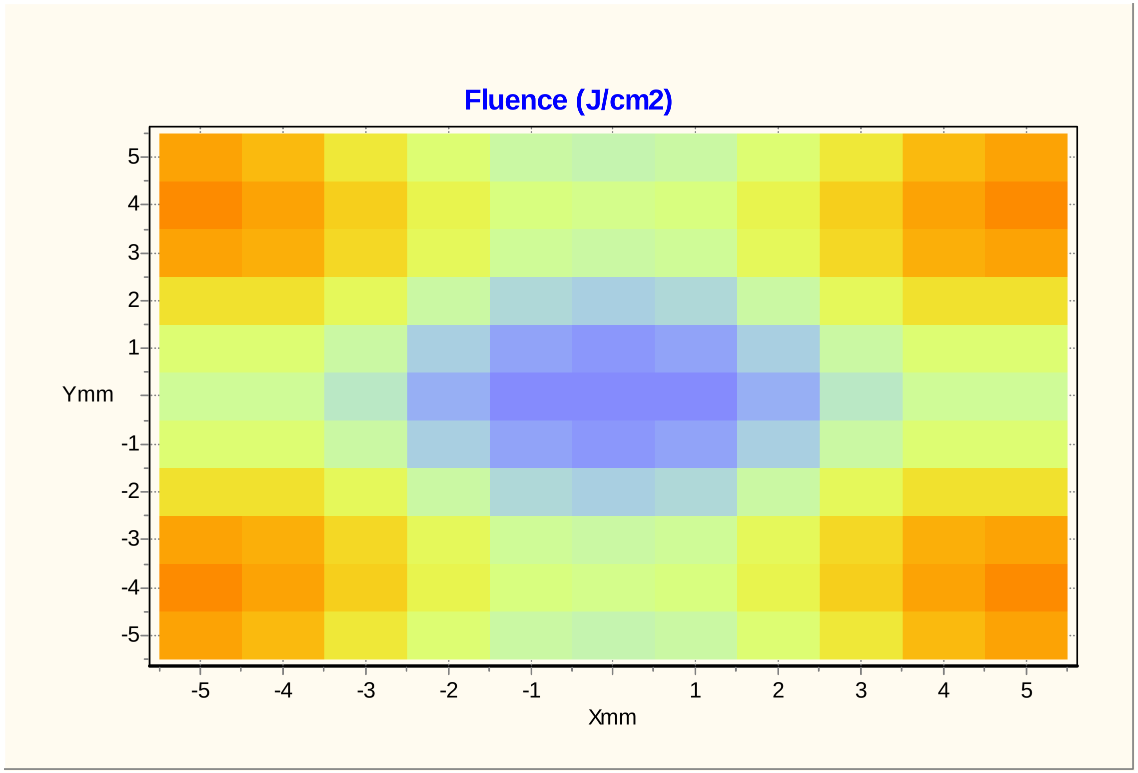
Richard M. Bionta
bionta1@llnl.gov

SINDA Cool Down Time Results

Cool Down Time is about 0.6 ms



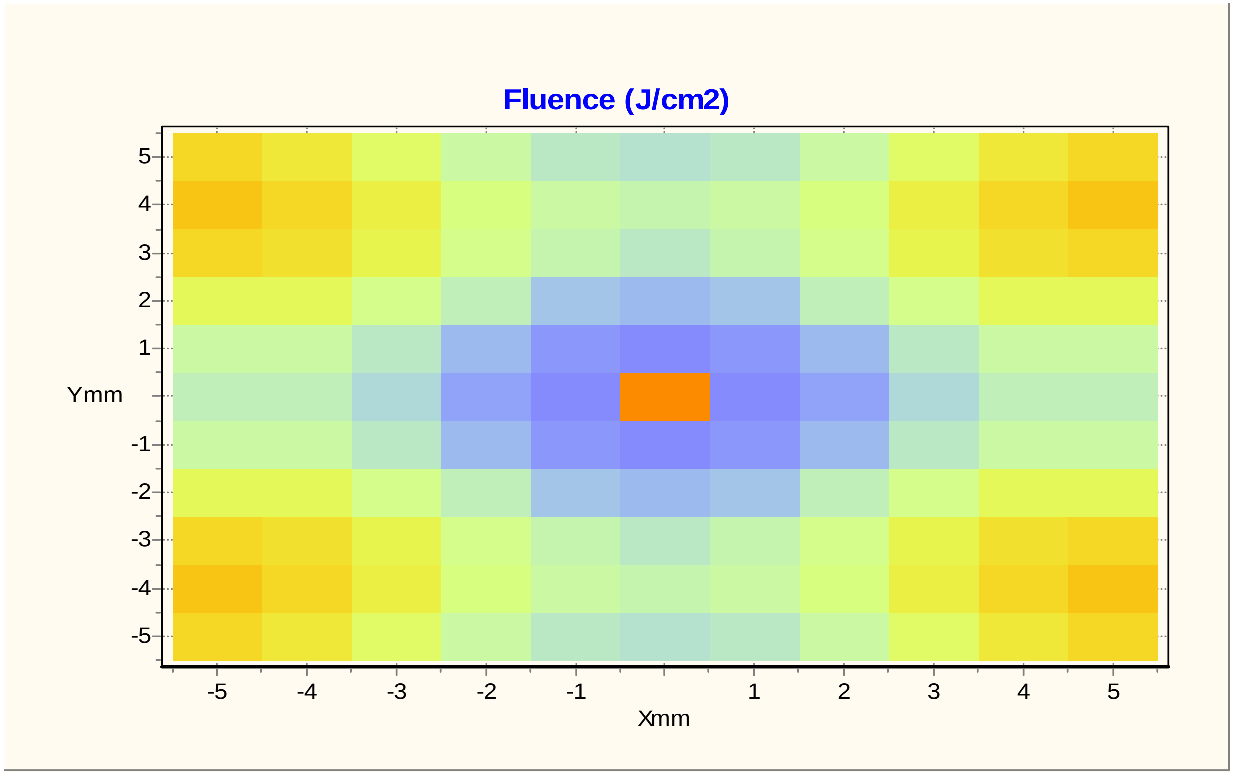
Response to 14.5 GeV Spontaneous



Energy Absorbed in 500um Silicon

Richard M. Bionta
bionta1@llnl.gov

Response to 14.5 GeV Spontaneous + 0.01% FEL



Energy Absorbed in 500um Silicon

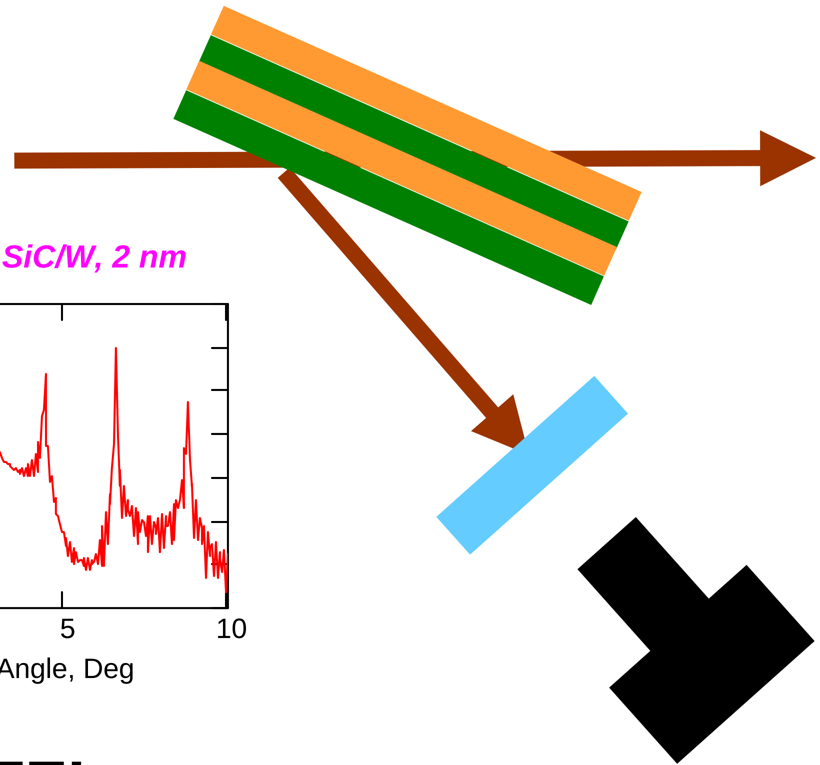
Richard M. Bionta
bionta1@llnl.gov

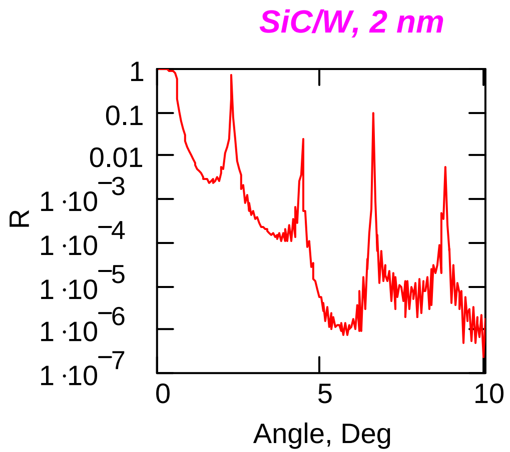
Total Energy Status

- Finalize detector design concept - Freidrick
  - Be or BeO for 800 eV
  - Si for 8000 eV
  - CMR sensor element Fabrication
  - BeO or Sapphire Heat sink
- Plan single pixel prototype - Ables
- Modeling
  - Xray:Calculate E vs xyz say 100 micron grid
  - Thermal: Model electro-thermal feedback

Richard M. Bionta
bionta1@llnl.gov

Indirect Imager



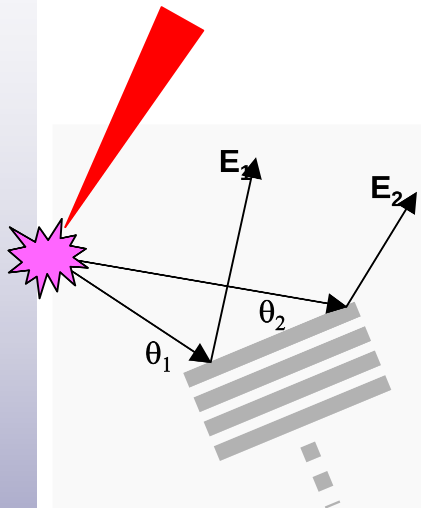


"Imaging Monochrometer"
1)Creates an image tightly selected in photon energy
2) Can be used to adjust FEL power downward

At full FEL power:
Use <10% reflective, survivable, Be/SiC ML

At reduced FEL power:
Use >90% reflective, Mo/Si ML

ML is similar to optic for Single Shot Spectrometer fielded at RAL

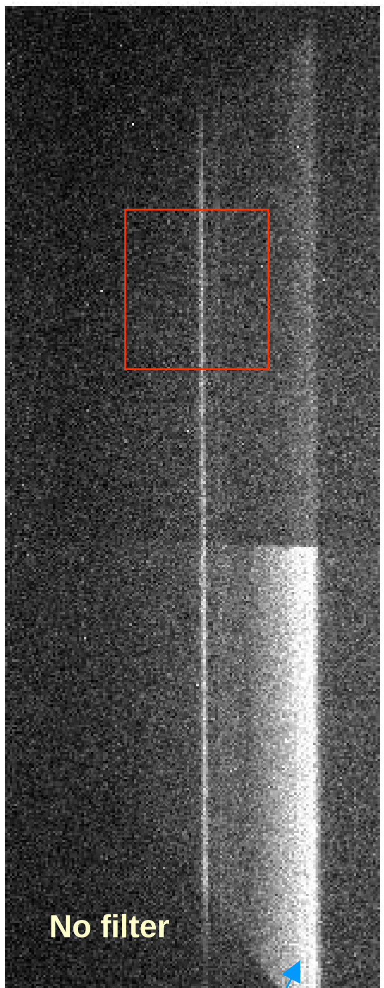


W/SiC bilayers

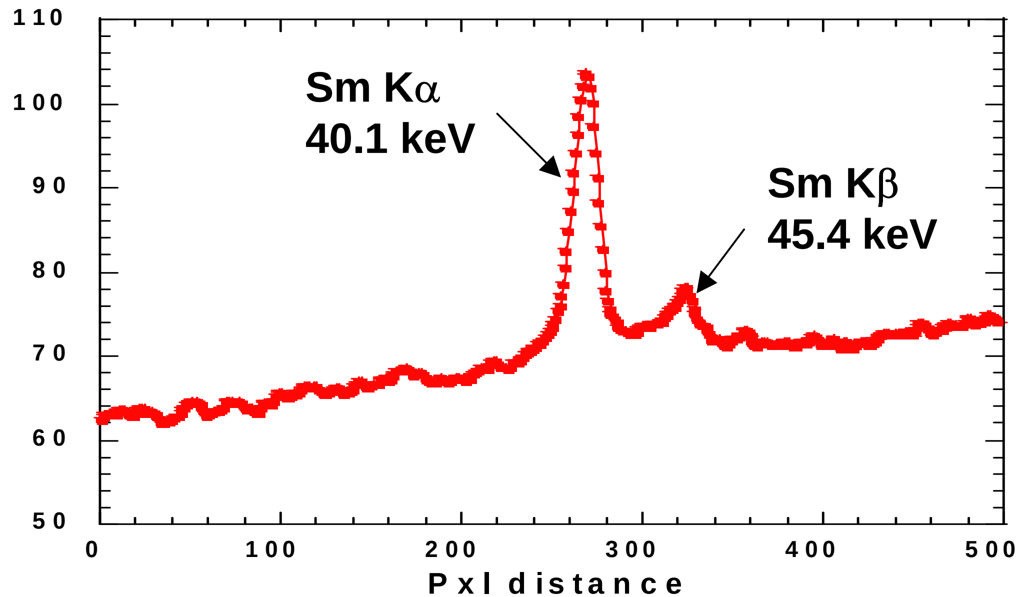
d = 2 nm

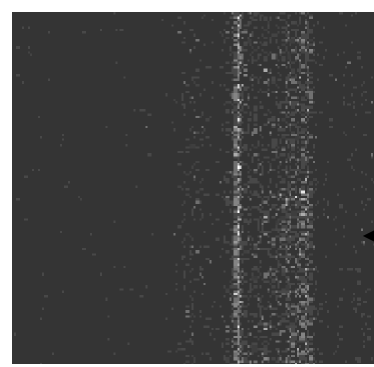
θ_B=0.45 deg

Reflectivity @40 keV > 90%



Straight-thru bkg

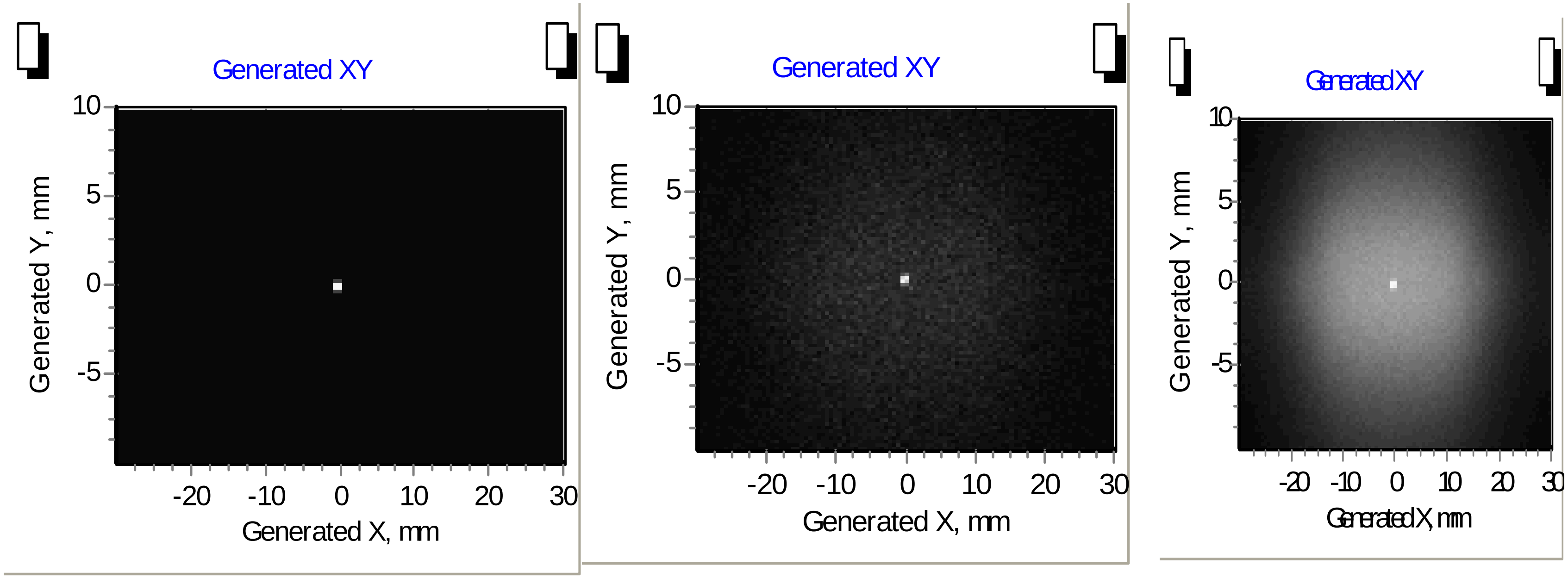


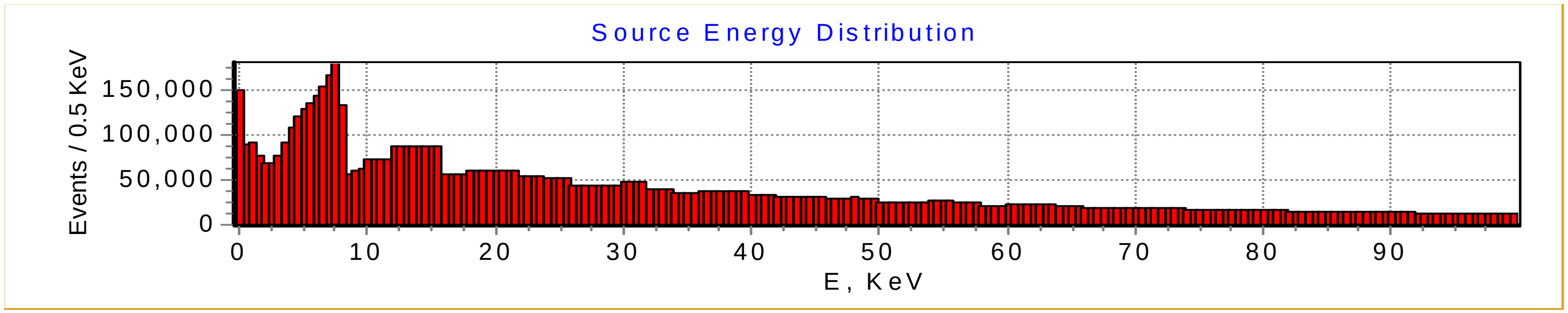


LCLS Monte-Carlo Simulation

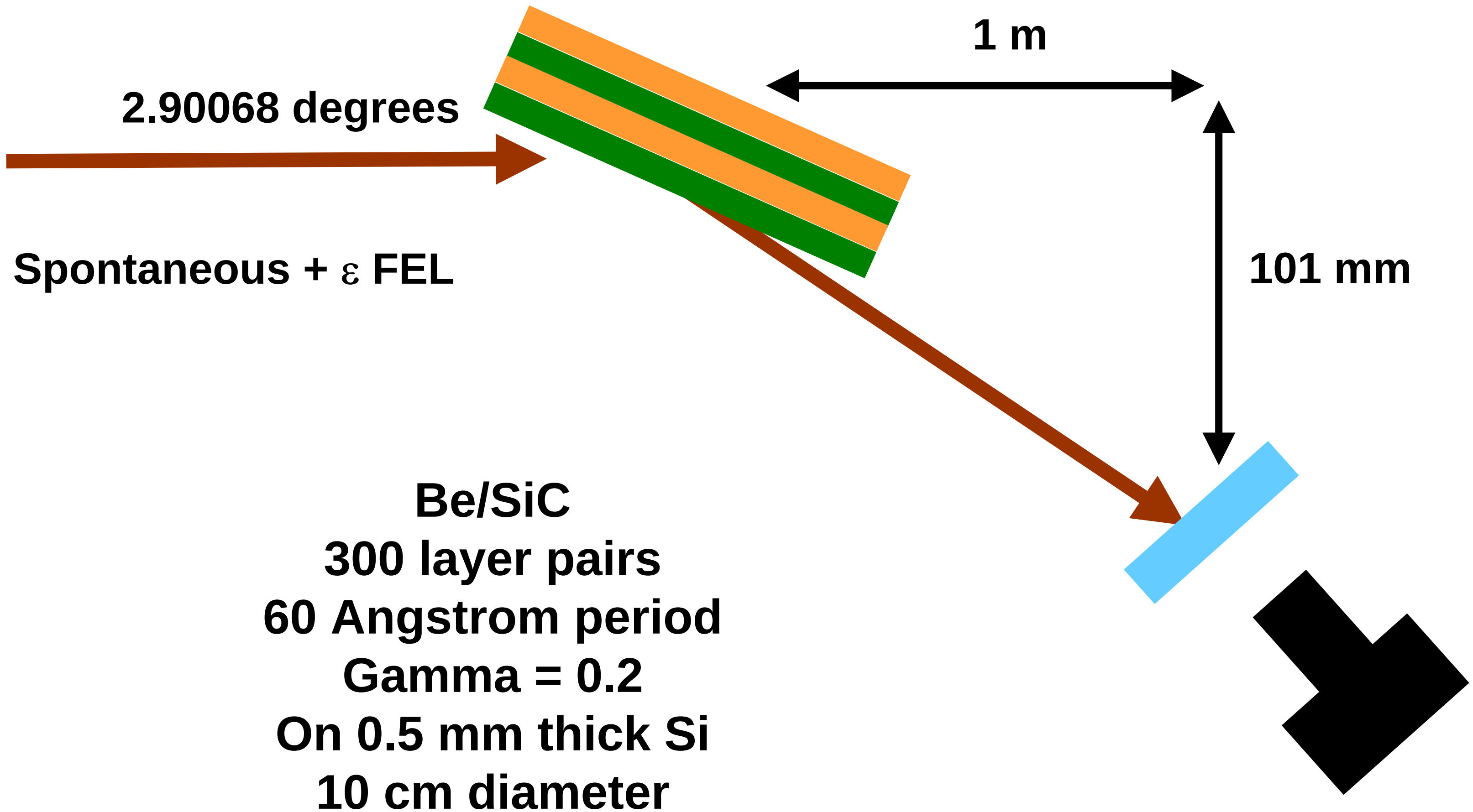
Monte Carlo Simulation of LCLS

100% FEL + Spontaneous | 1% FEL + Spontaneous | 0.1% FEL + Spontaneous



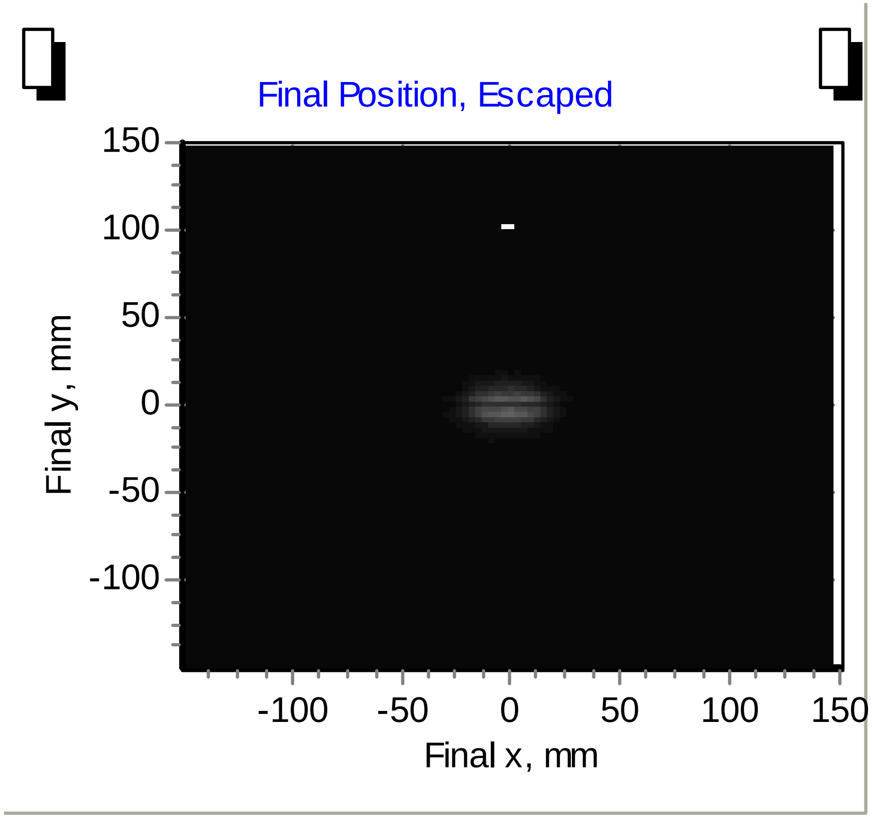


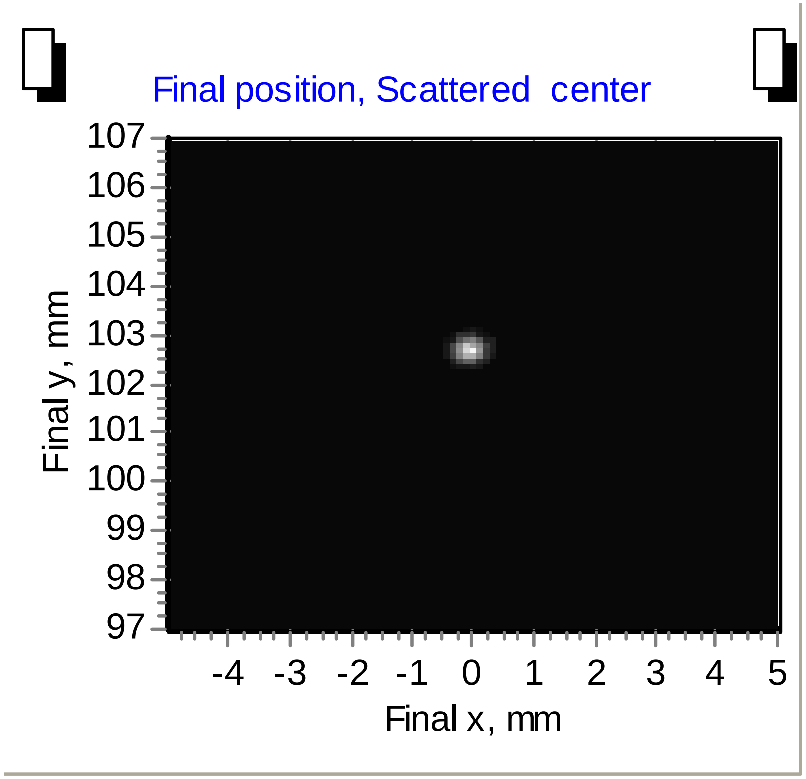
Indirect Imager Simulation



Richard M. Bionta
bionta1@llnl.gov

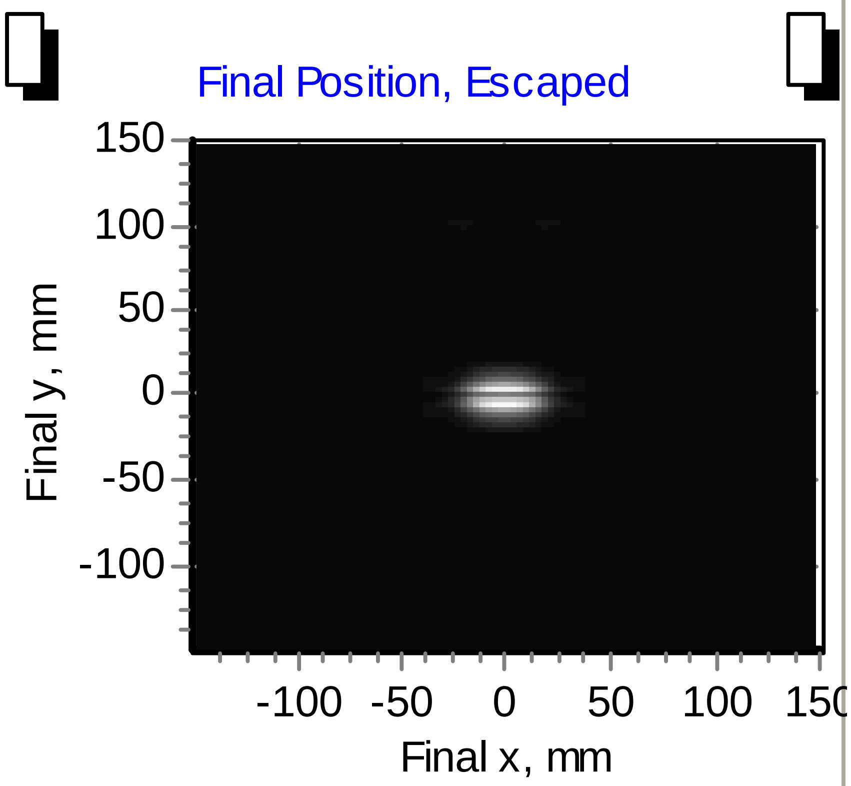
For Full Power FEL ML allows imager to operate w/o damage

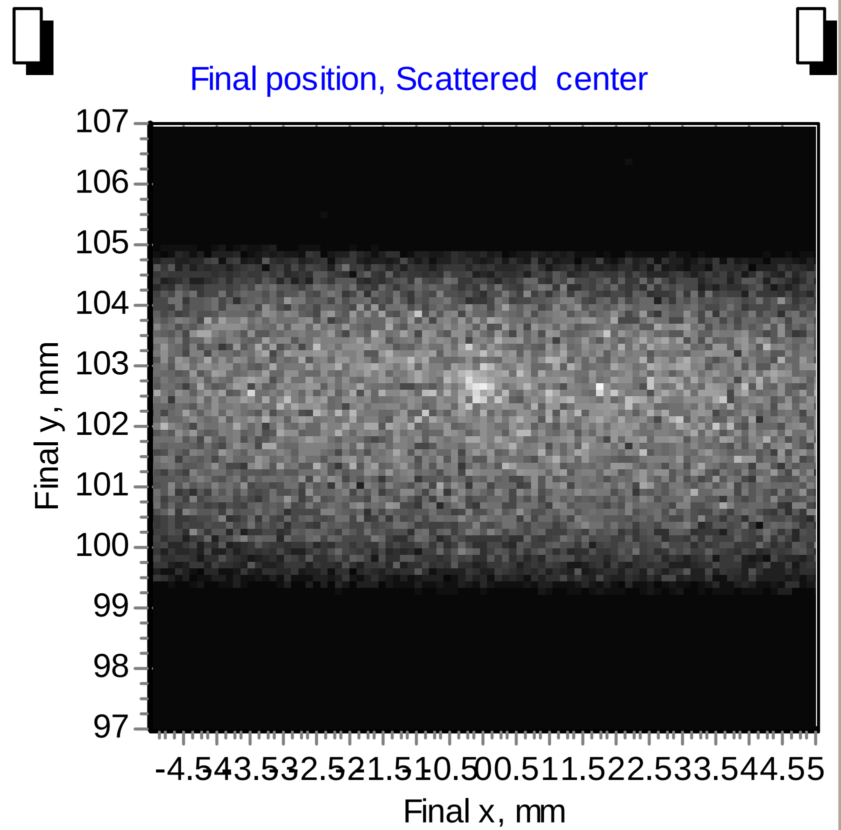




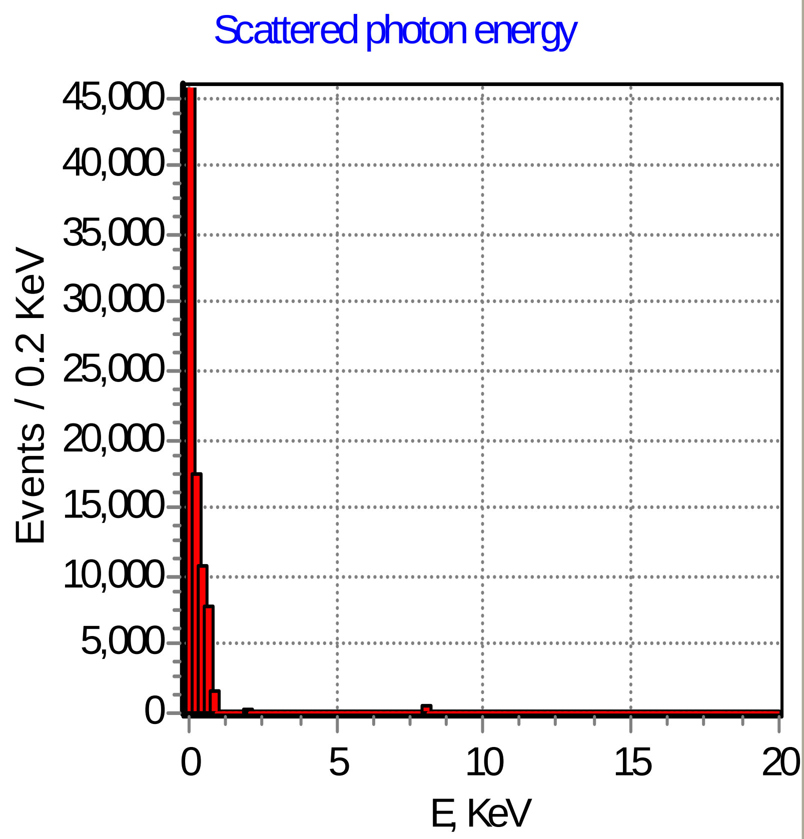
Richard M. Bionta
bionta1@llnl.gov

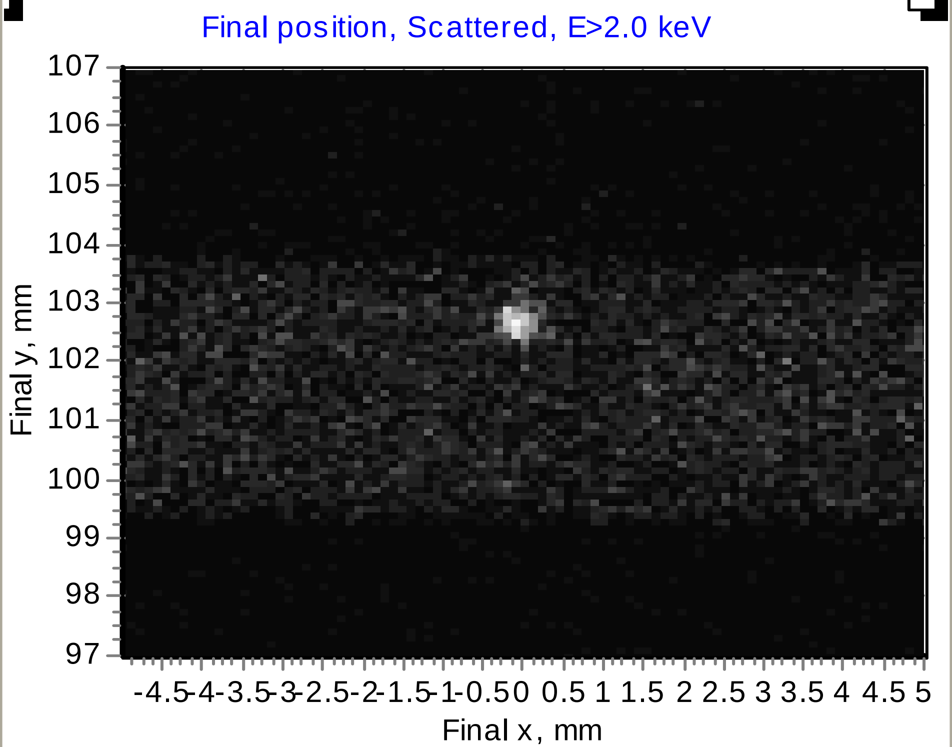
0.1% FEL


Final Position, Escaped
150
100
50
0
-50
-100
Final y, mm
-100 -50 0 50 100 150
Final x, mm


Final position, Scattered center
107
106
105
104
103
102
101
100
99
98
97
Final y, mm
Final x, mm

Low Energy Background Dominates





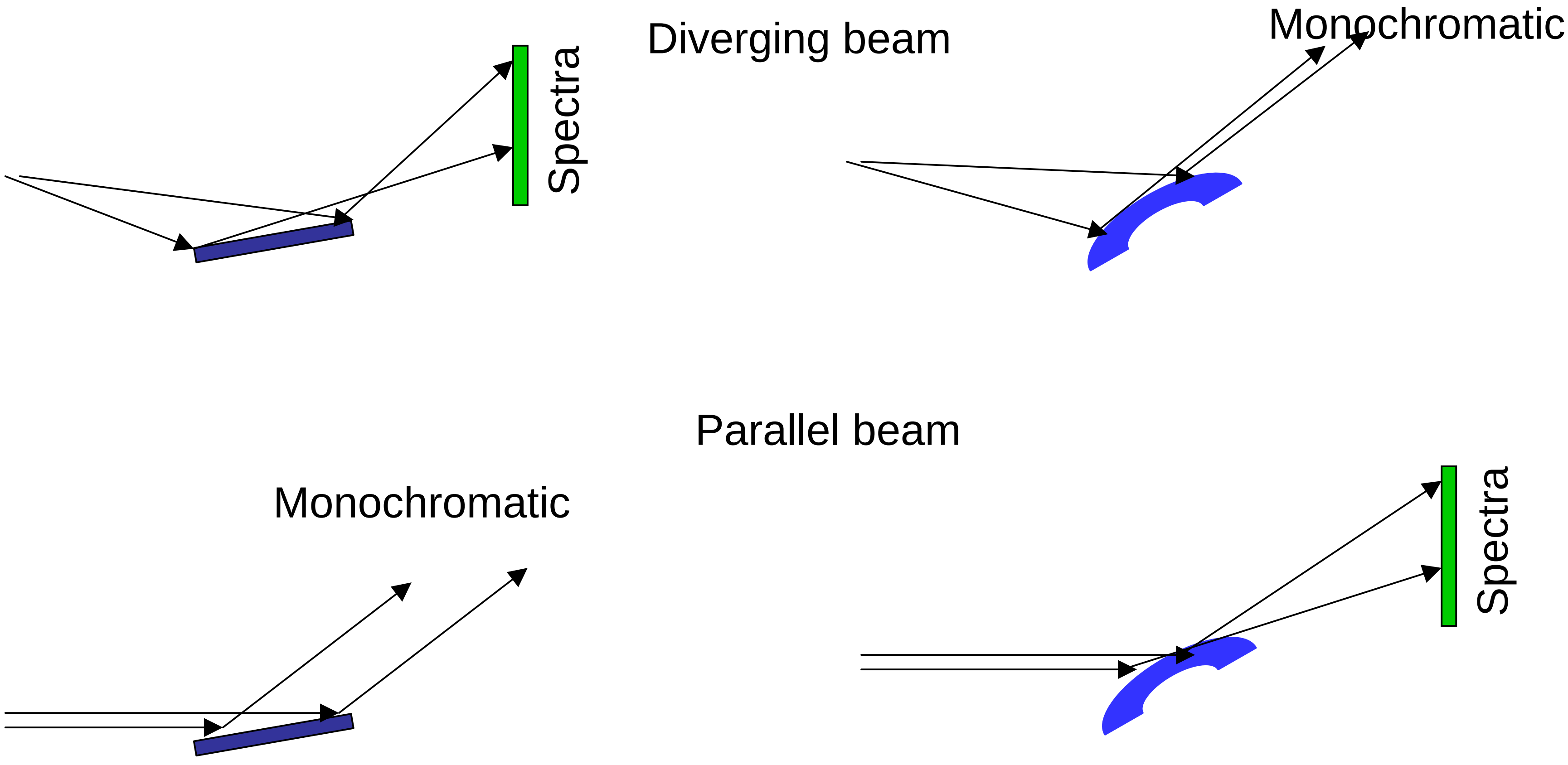
E>2.5 keV
Cleans up signal !

Indirect imager status

- Continue modeling and selecting ML
- Fabricate & test prototype ML
- Test ML at TTF damage experiment

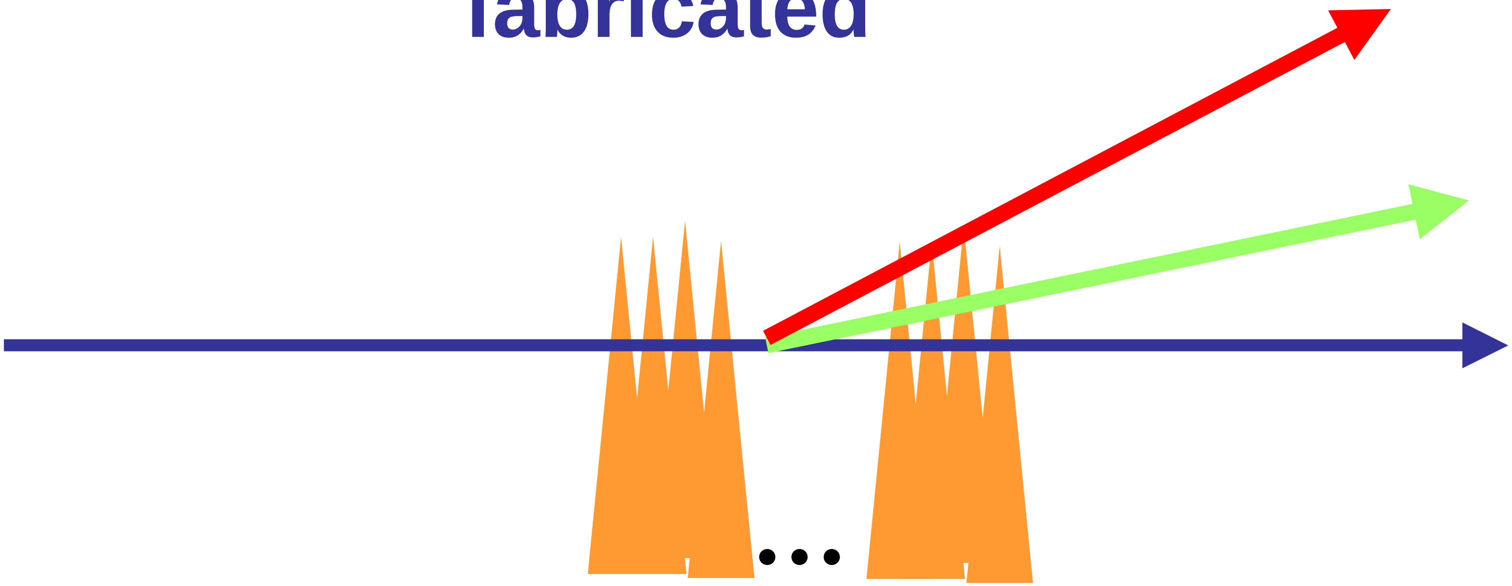
Richard M. Bionta
bionta1@llnl.gov

Spectrometers & Monochrometers

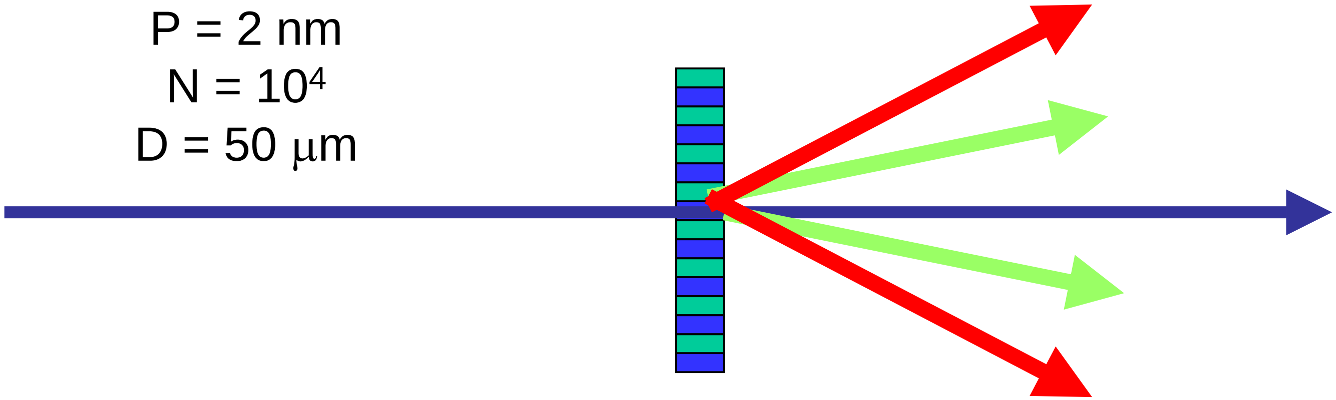


Richard M. Bionta
bionta1@llnl.gov

Transmissive Spectrometers can be fabricated



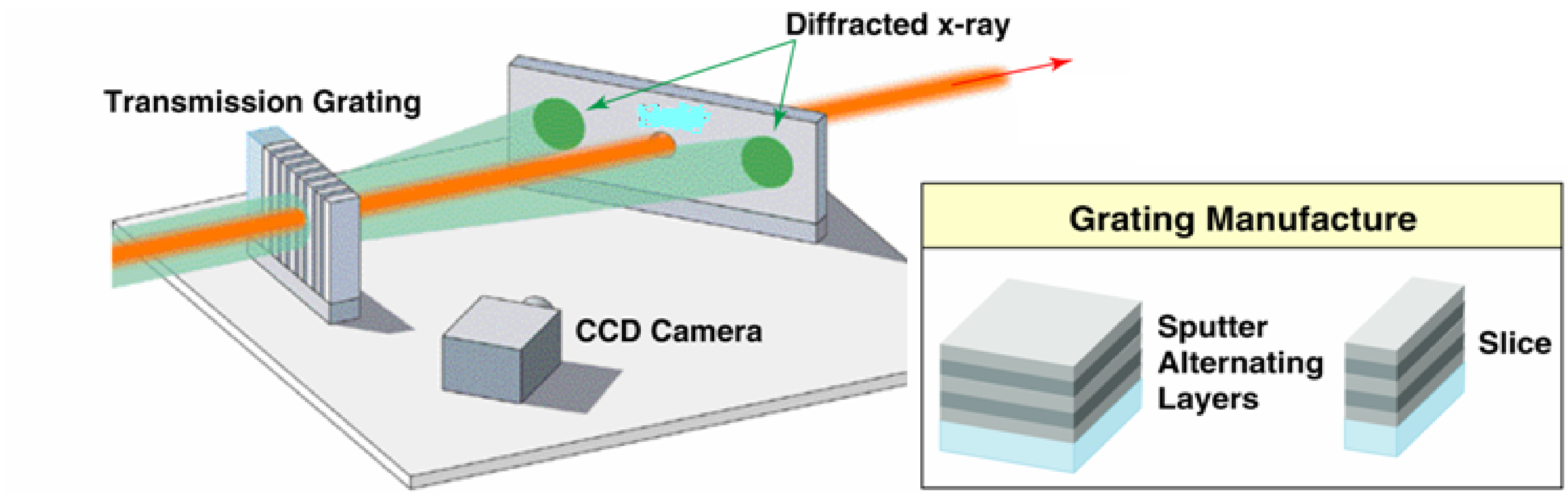
P = 2 nm
N = 10^4
D = 50 μm



$$\frac{\Delta E}{E} = \frac{1}{N}$$

Richard M. Bionta
bionta1@llnl.gov

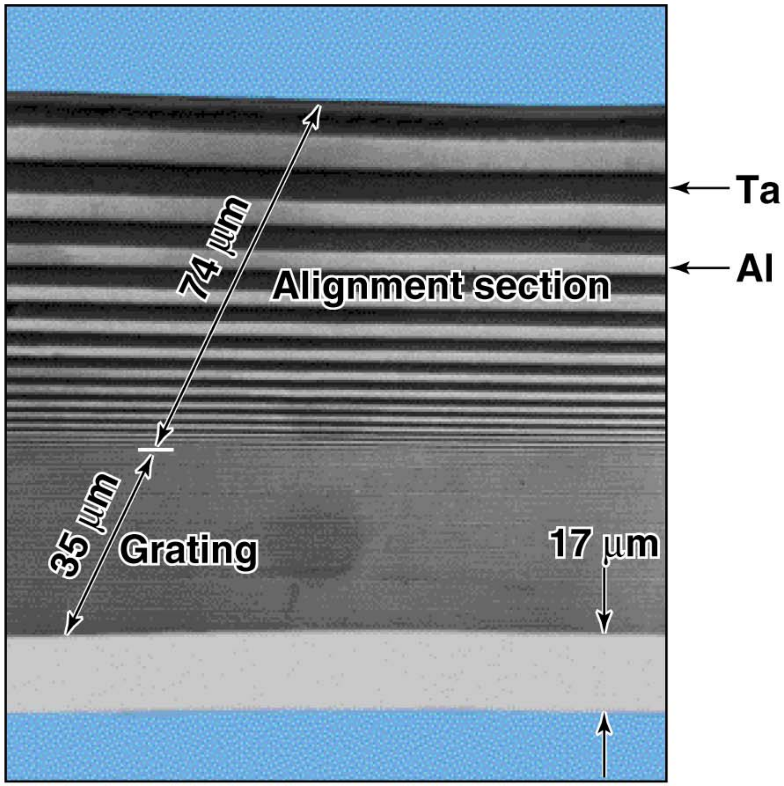
Sputter sliced gratings

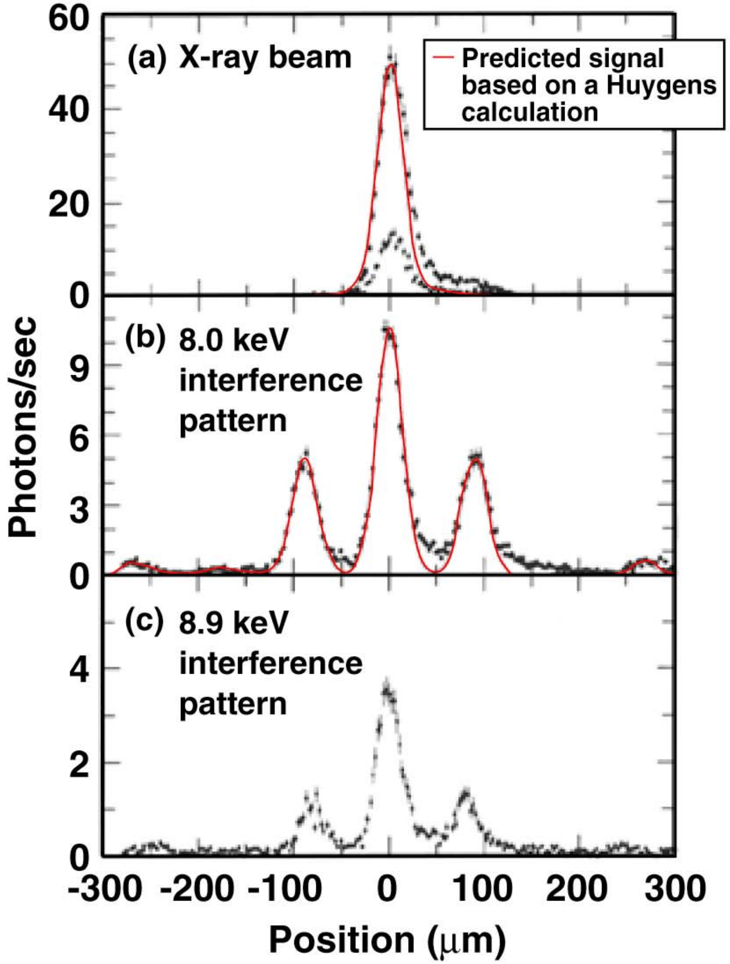


Material Parameters at Ephoton = 8.271 KeV	Even Zones	Odd Zones	Units
Material	Be	B4C	
Attenuation Length	6632	1768	μm
1 π phase shift length	15	10.4	μm
Transmission through 33 µm	99.5	98.2	%
Phase shift through 33 µm	1.09	1.59	2*π
Surface dose at z = 65 m	0.002	0.007	eV/atom

Richard M. Bionta
bionta1@llnl.gov

A 7000 Å period transmissive diffraction grating has successfully been built and characterized





R. M. Bionta, Appl. Phys. Left., 51 (10) 7 Sept. 87

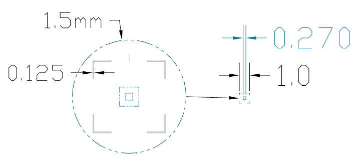
P01494-at-u-012

Spectrometer Status

- Conceptual designs to be evaluated with Kirchoff code

Richard M. Bionta
bionta1@llnl.gov

TTF Damage experiment set for Oct 2005 to test models at 40 eV

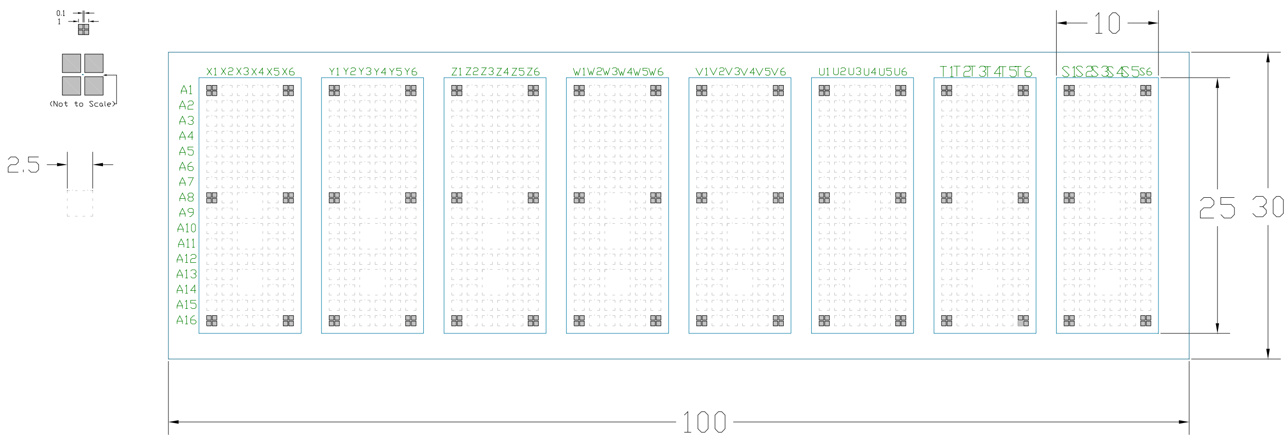


<Si, SiC, B4C, SiC/B4C> X2

100mmx30mm

Shot size ~270μ Sq

7.5mm x 16mm x 1mm spacing



Scale = mm

Sample cassette

Richard M. Bionta
bionta1@llnl.gov

Response to Oct. 2004 FAC XTOD Findings

- X-ray beamline controls not defined. Steve Lewis on-board full time.
- Details of designs are sparse, Engineers and physicists hired in Feb. User workshops should be aimed at collecting more detail. Hutches?
- There is not enough effort going into the shot-by-shot beam diagnostics. CCD Cameras for shot-by-shot imaging under study. Total energy will run at 120 Hz. Concepts and requirements for beam monitoring at 120Hz are lacking as windowless ion chamber dropped to meet funding constraints. Studying option of monitoring florescence or ionization in gas attenuator.
- There is not enough effort going into optics stability. This may be a problem for the flipper mirror and proposed FEE POMs.
- Concentrate on LCLS-specific problems such as shot-by-shot diagnostics, data flow, feedback control, preservation and measurement of coherence Emphasis has been on comissioning and first-light.

Richard M. Bionta
bionta1@llnl.gov

Response to Oct. 2004 FAC XTOD Findings

- The detector advisory committee should coordinate the effort of LCLS and MIE
- Identification and communication of critical issues to LCLS experimenters should be a priority - Arthur
- Do not fund detector efforts unless resources are sufficient to produce a useful end result - XTOD costs documented in P3 and should come in within the estimate + contingency.

Richard M. Bionta
bionta1@llnl.gov

Summary

- XTOD transports x-ray beam to users and provides optics and diagnostics for LCLS commissioning and monitoring
- Basic imaging diagnostics and attenuator systems understood and supported by calculations and prototypes. The development of the other instruments will proceed in a serial fashion with priority given to commissioning diagnostics
- Beam models now exist allowing detailed modeling of the instrumentation
- New layout, commissioning strategy, and risk analysis must be carried out on new layout proposal
- XTOD is now engaged in serious R&D and Engineering effort to support procurement and fabrication in FY06

Richard M. Bionta
bionta1@llnl.gov