

LCLS Ultrafast Science Instruments: Status

J. B. Hastings
Project Director

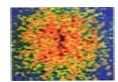
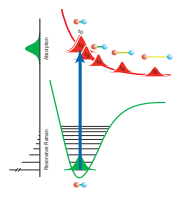
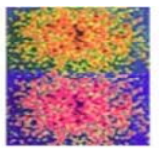
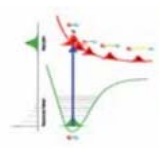
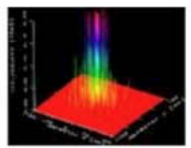
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J. B. Hastings
jbh@slac.stanford.edu

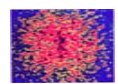


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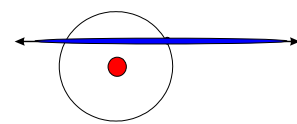
SLAC Report 611



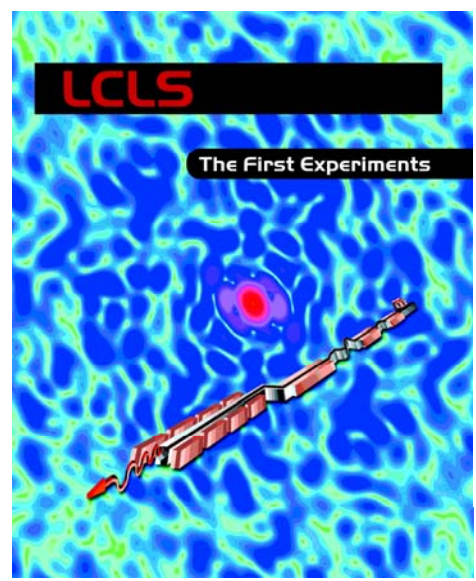
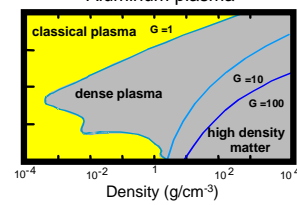
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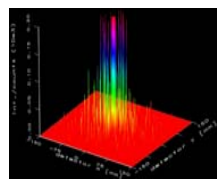


Aluminum plasma



Program developed by international team of scientists working with accelerator and laser physics communities

“the beginning... not the end”



Diffraction studies of stimulated dynamics (pump-probe)

Coherent-scattering studies of nanoscale fluctuations

Atomic, molecular and optical science

High energy density science

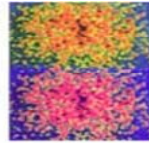
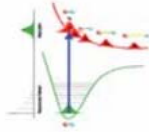
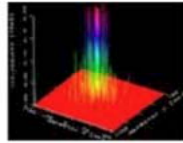
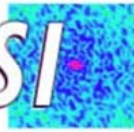
Nano-particle and single molecule (non-periodic) imaging

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jbh@slac.stanford.edu



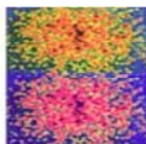
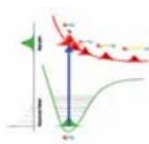
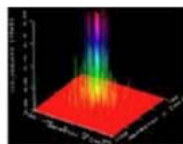
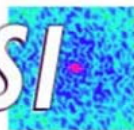
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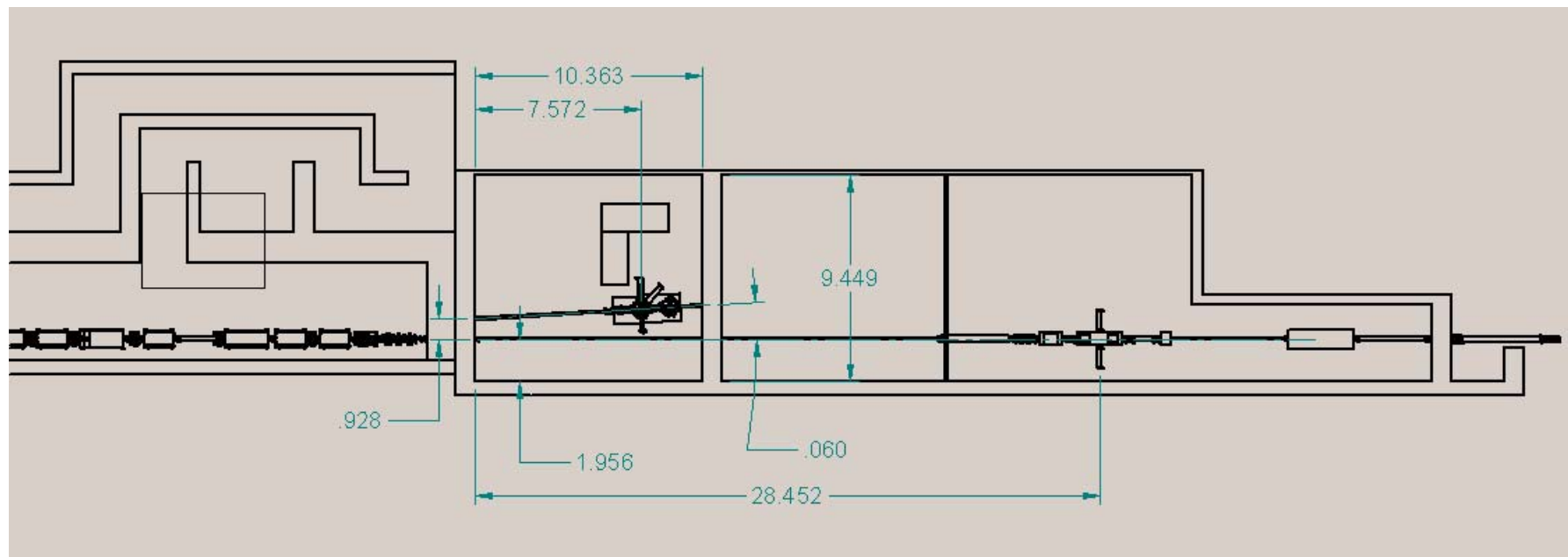
LUSI Scope

- Build instruments for hard x-rays that address 3 Thrust Areas: X-ray pump-probe, XPCS, Coherent x-ray imaging
- *Include one additional instrument, to address the soft-x-ray portions of pump-probe and coherent imaging Thrust Areas*
- Detector development

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A soft x-ray pick-off mirror in the FEE could provide a 'soft x-ray beamline' for Hutch 1 (and maybe Hutch 2), allowing easy switching between experiments

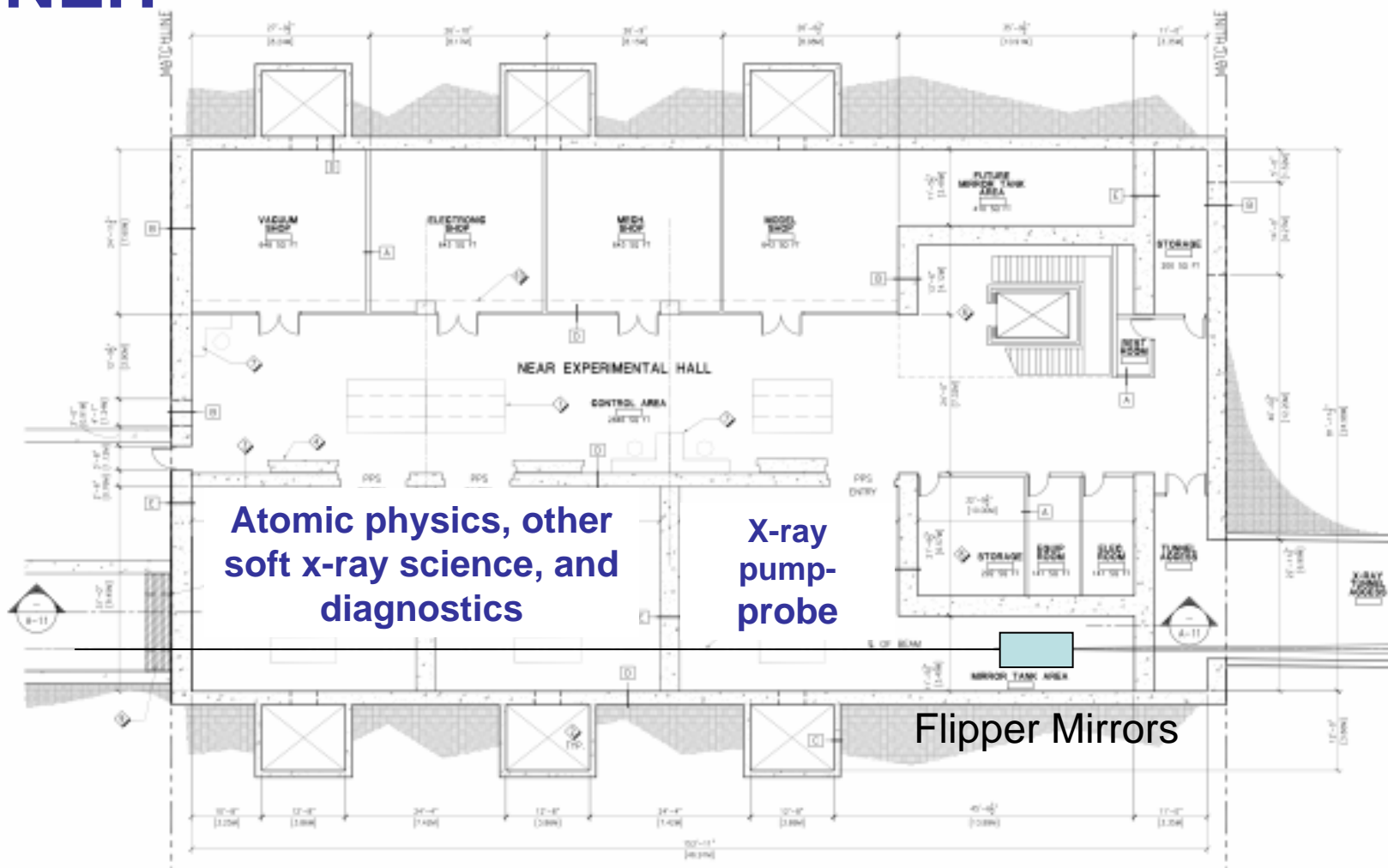
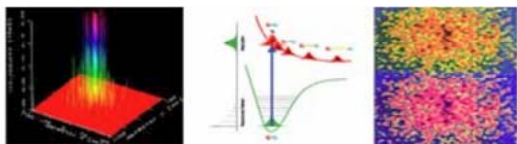


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jbh@slac.stanford.edu



LUSI NEH

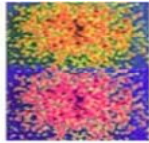
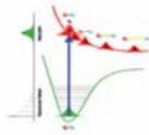
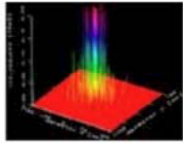


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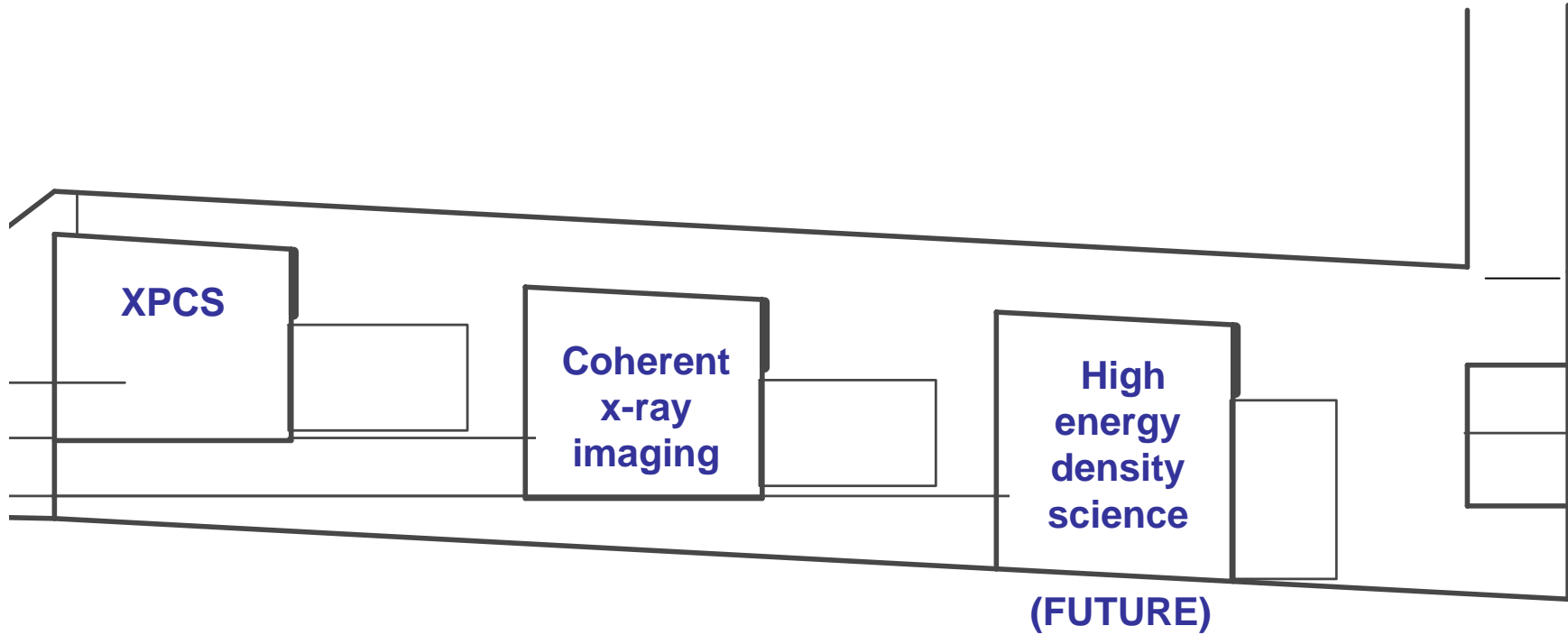
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jbh@slac.stanford.edu



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FEH

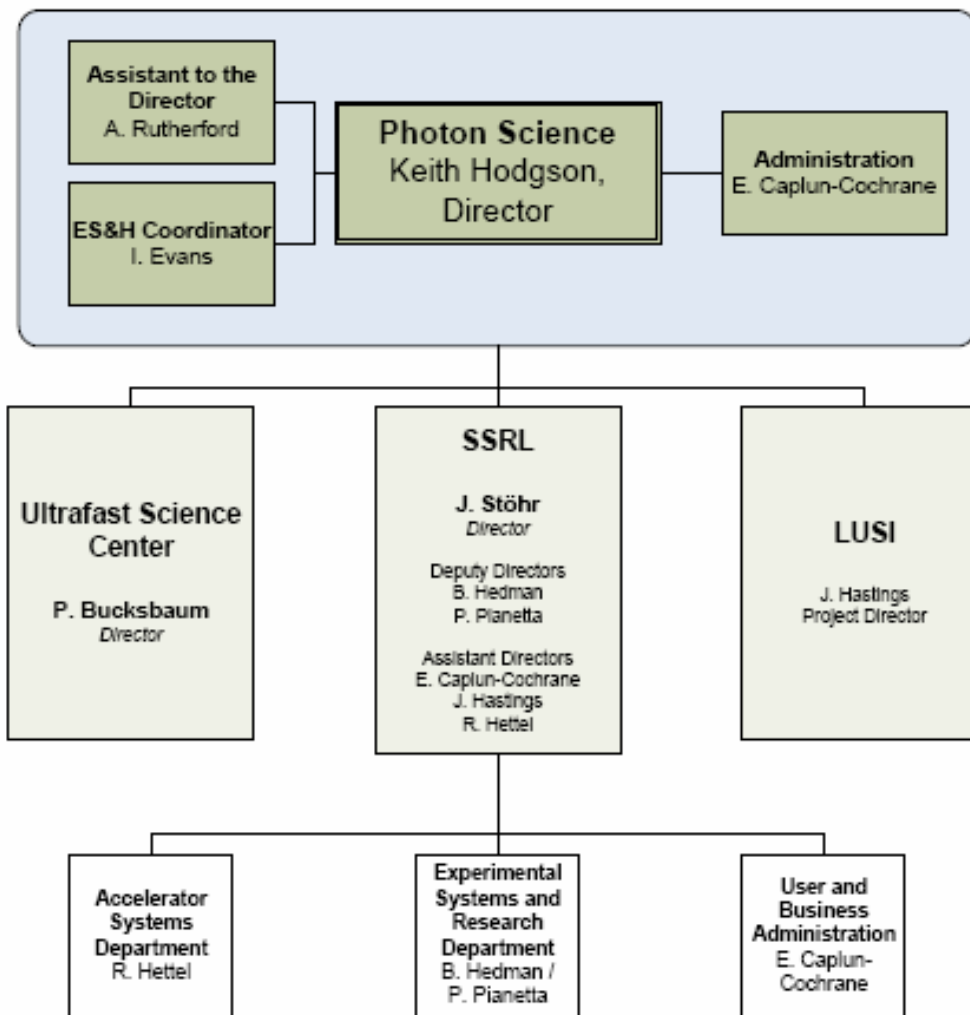
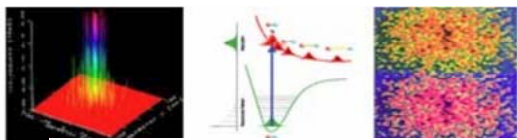


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jbh@slac.stanford.edu



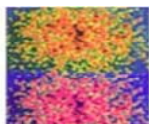
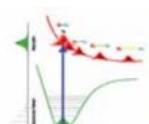
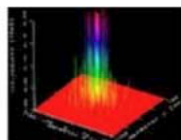
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J. B. Hastings
jbh@slac.stanford.edu





Keith Hodgson
Photon Science Division

Jerry Hastings
LUSI Project Director
Nadine Kurita
Chief Engineer
TBD*
LUSI Project manager

LCLS Science Teams

Engineering Development
 N. Kurita
 Group Leader

 4-5 Engineers
 2-3 Designers

Administration
 LUSI Proj. Manager
 Group Leader

 Budget
 ES&H
 PMCS
 Database
 Purchasing
 Administration

Instrument Scientists
 J. Hastings
 Group leader

Instrument Scientist 1*
 Instrument Scientist 2**
 Instrument Scientist 3**
 Instrument Scientist 4**

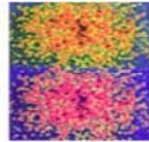
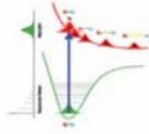
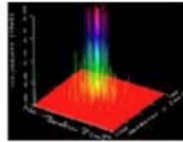
*in process
 **req. open

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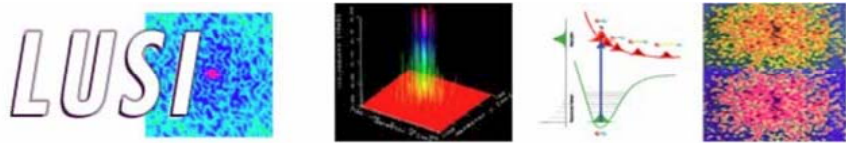


LUSI



Plans for FY2006

- ***Initial funding has been provided (\$1.9M)***
- ***Staff up, including 3 Instrument Scientists***
 - Chief engineer hired
 - Project manager sole source req. approved
 - Excellent candidates have applied for all instrument scientists
 - In discussion with excellent candidates for x-ray optics
- ***Prepare CDR***
- ***Lehman review in ~July-August – CD-1***
- ***Continue design - Another Lehman review in ~ November***



Technology needed for the science opportunities

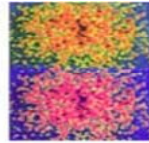
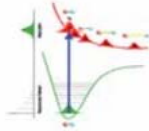
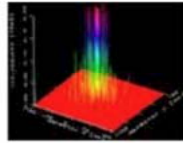
- ***Detector development***
- ***Laser – x-ray timing***
- Damage mitigation
- Diagnostics
 - Pulse length
 - Pulse energy
 - Pulse wavelength
- Novel x-ray optics

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jbh@slac.stanford.edu



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Detector Development

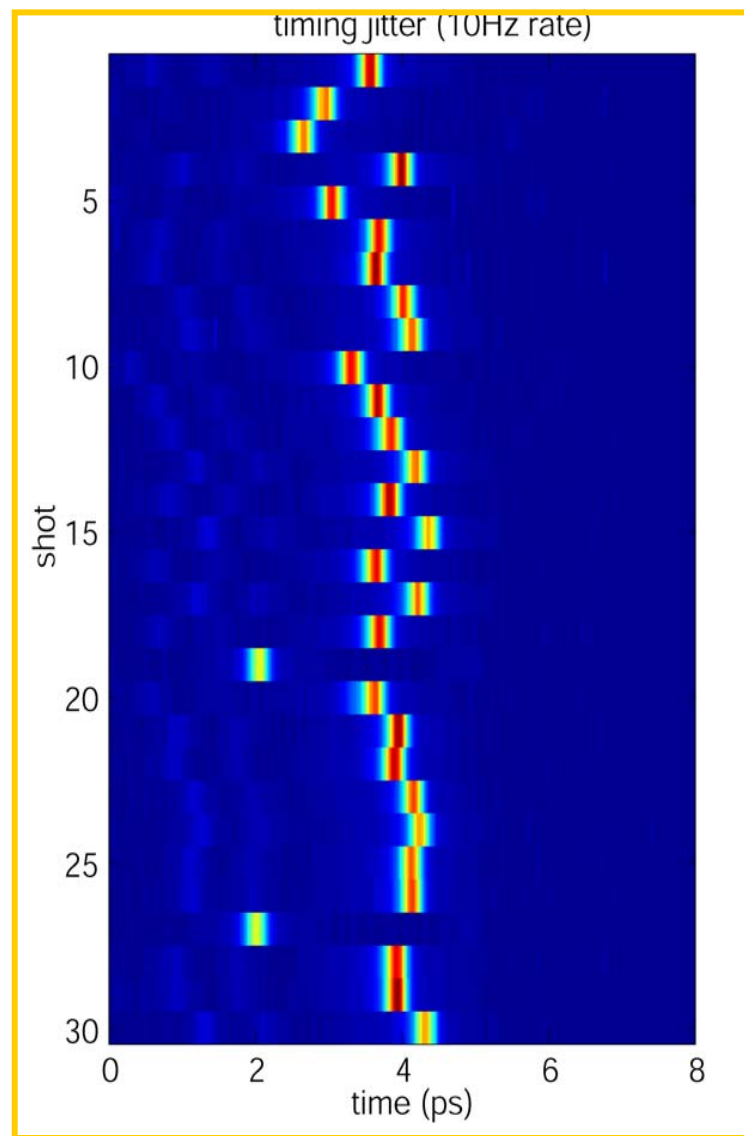
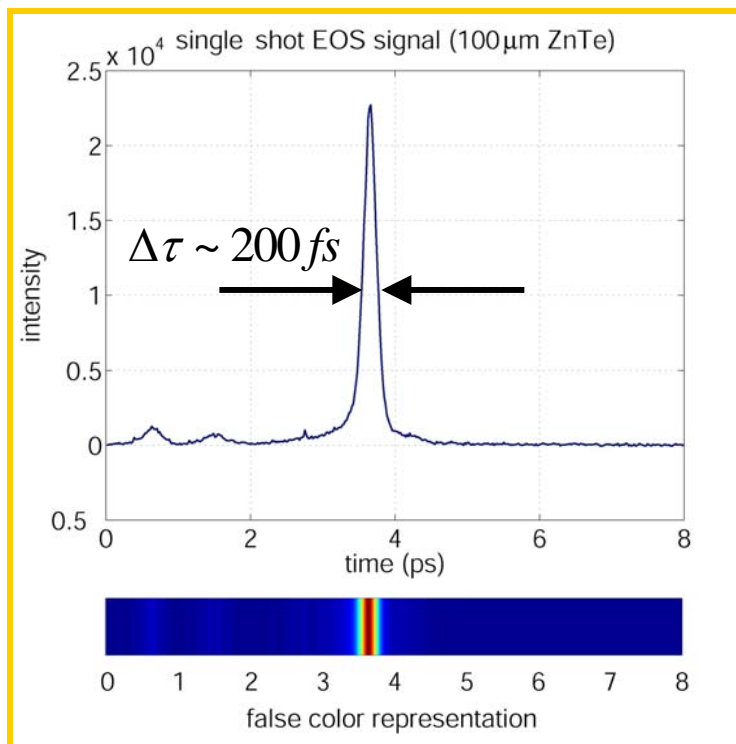
- LCLS experiments need new detector technology
- Dual development strategy for fast 2-d detectors
 - Several technologies look promising, no clear leader
 - LCLS will pursue one strategy
 - LUSI will try a different technology
 - Both prototypes should be ready by 2009
- LCLS Detector Advisory Committee review
 - 9-10 Feb 2006
 - Good progress on Cornell design
 - Support for BNL plan
 - Integrate detector design **completely** into the experiment
 - Report on need for streak camera in July

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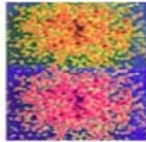
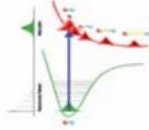
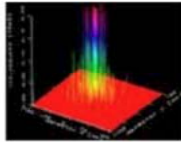
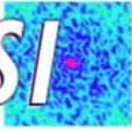
J. B. Hastings
jbh@slac.stanford.edu



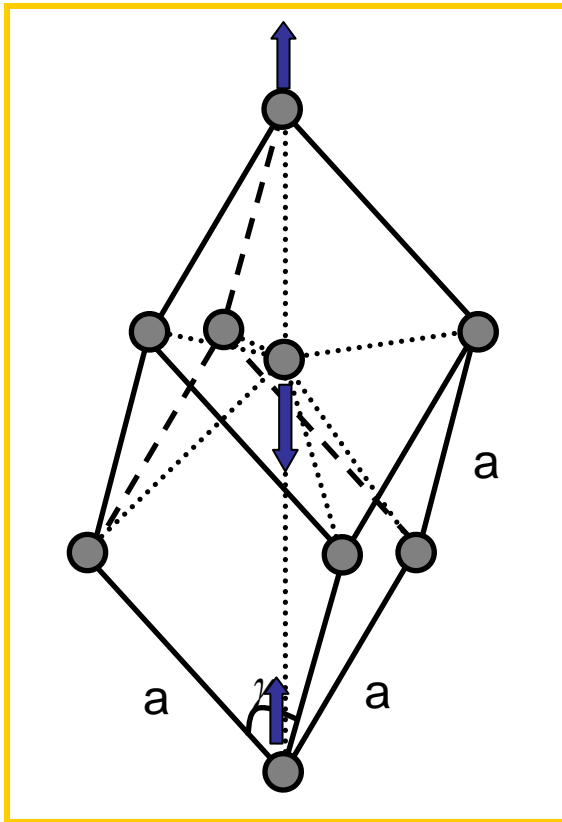
(Typical) Single-Shot EOS Data at SPPS (100 μ m ZnTe)



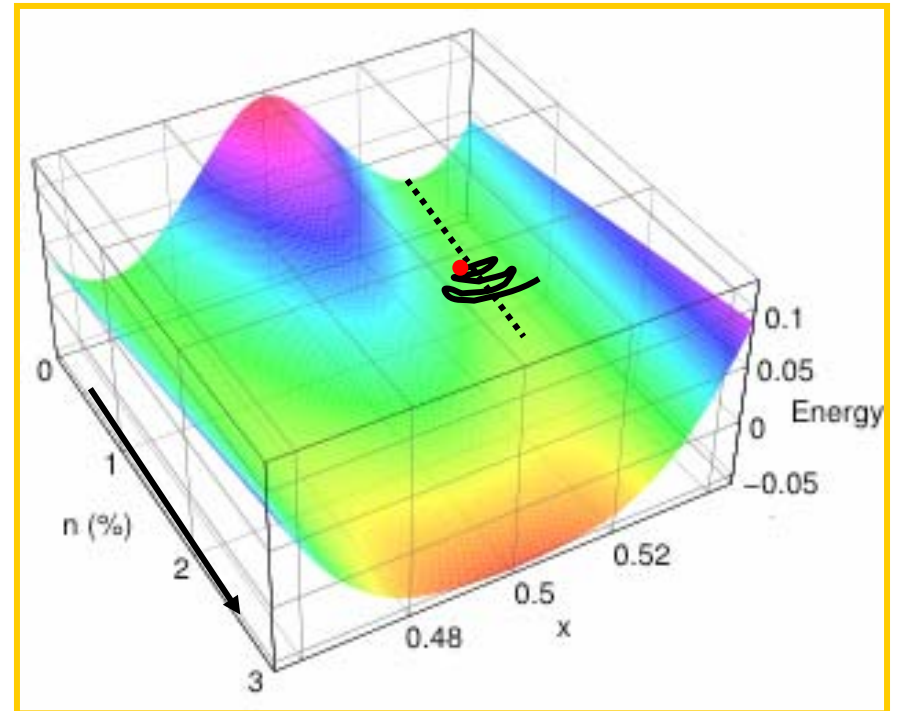
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Bi structure

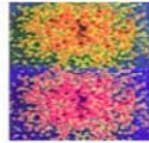
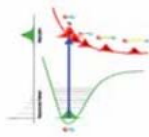
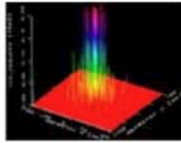


Potential Energy vs. Carrier Concentration

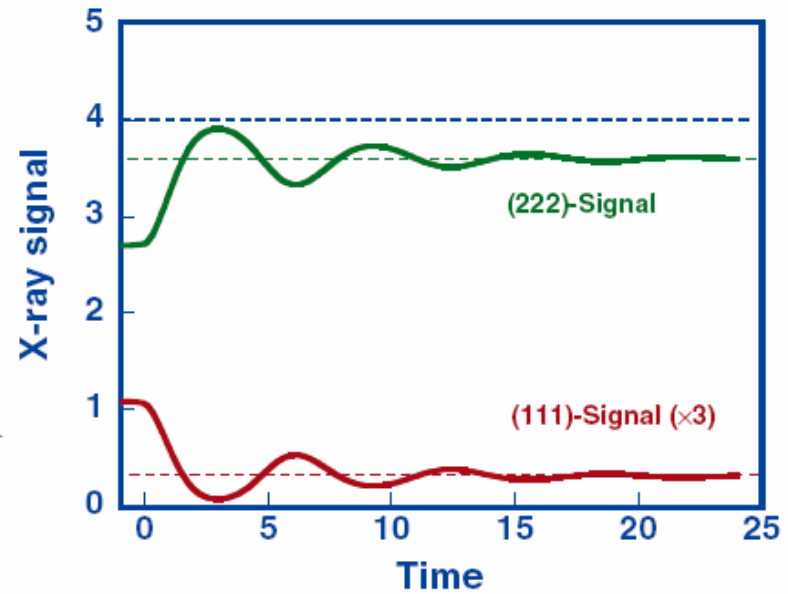
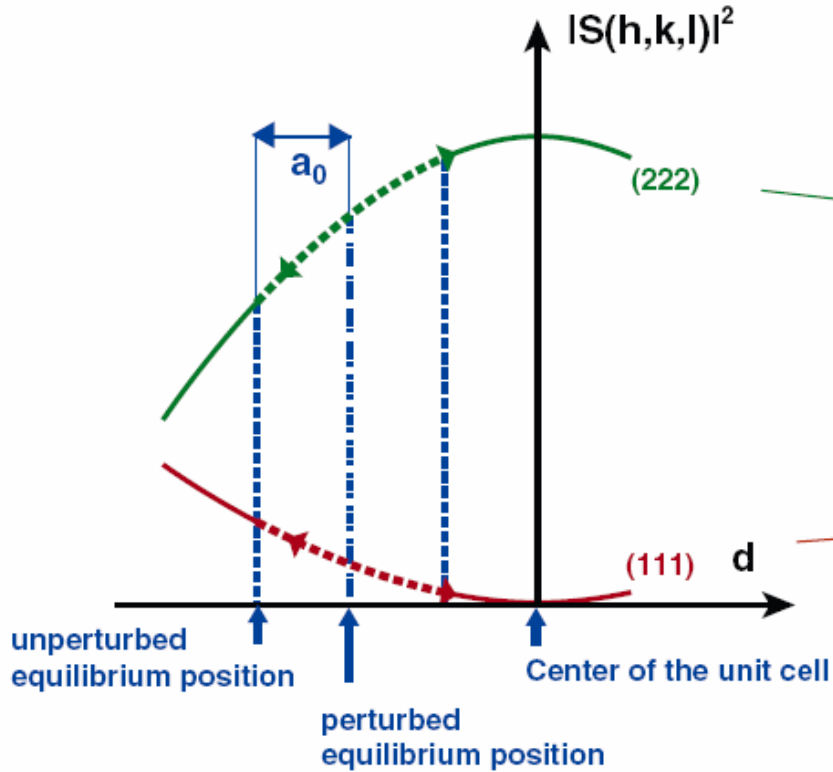


Murray *et al.* PRB 72, 060301 (R) (2005).

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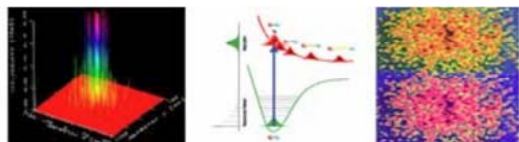


Femtosecond x-ray measurements
Of coherent vibrations in Bi



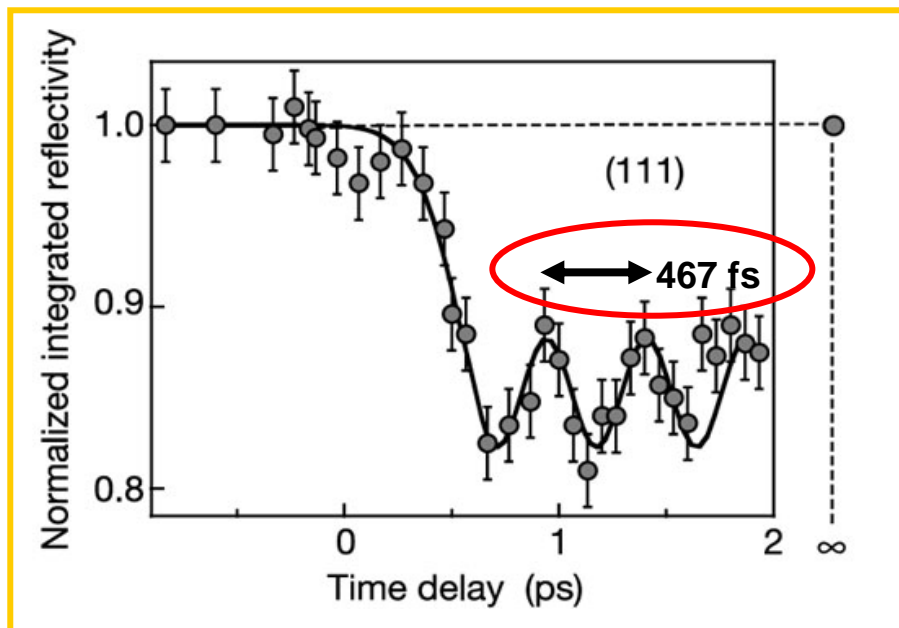
Estimated oscillation amplitude: $a_0 \approx 0.15 \text{ .. } 0.2 \text{ \AA}$
(nearest neighbor distance: 3.47 \AA)

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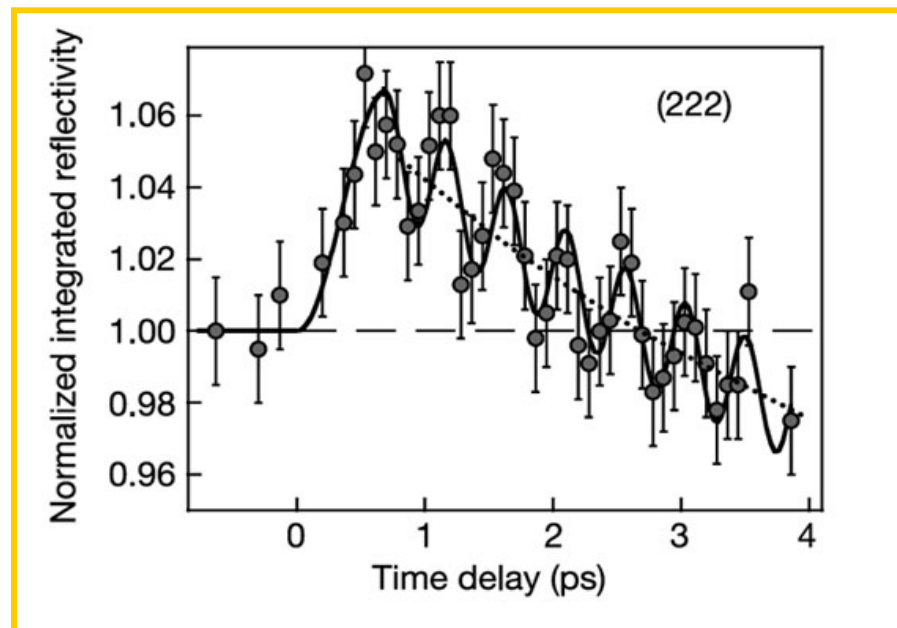


X-rays diffraction – direct probe of atomic motion

111 forbidden in simple cubic



222 “perfect” in simple cubic



- Measure large displacements: 15–20 pm
- Very strong softening 2.9- \rightarrow 2.1 THz
- Used very low flux plasma source: long scans, large error bars

Sokolowski-Tinten *et al.*, Nature, 422 (2003)

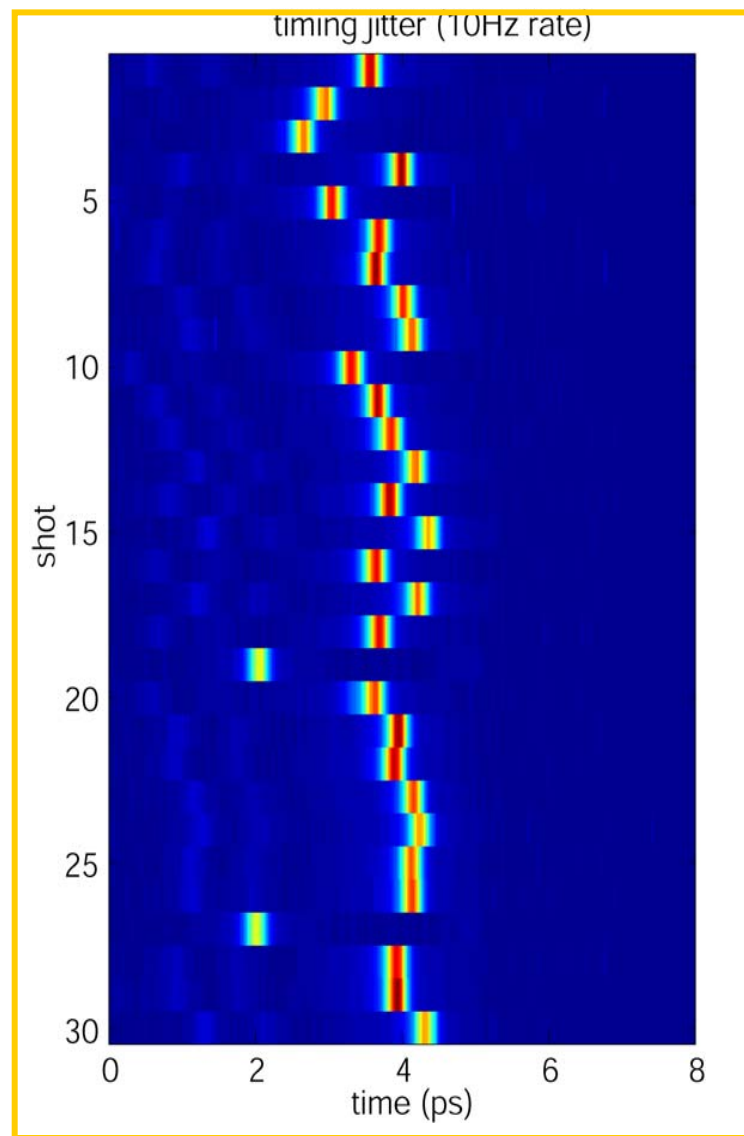
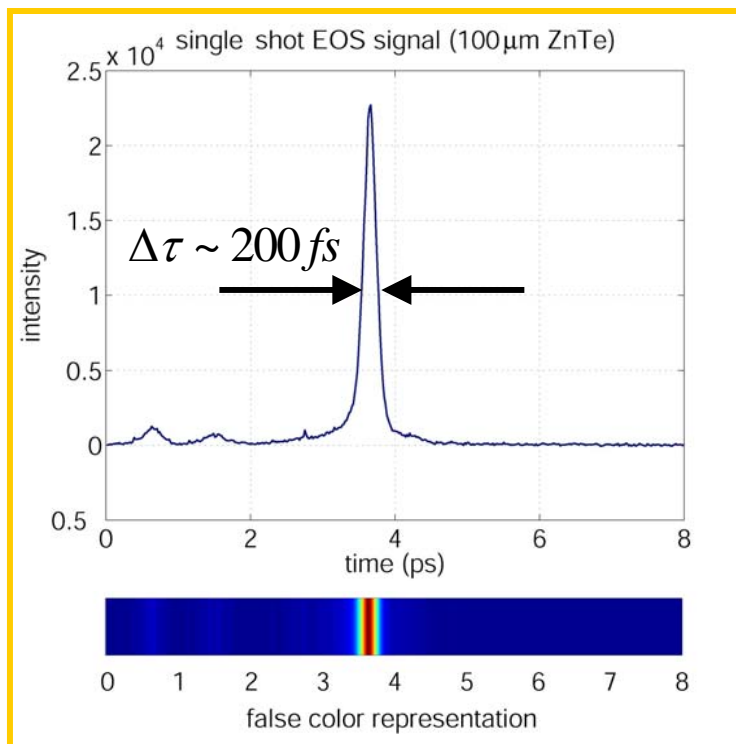
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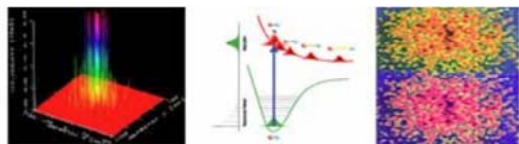
J. B. Hastings
jbh@slac.stanford.edu



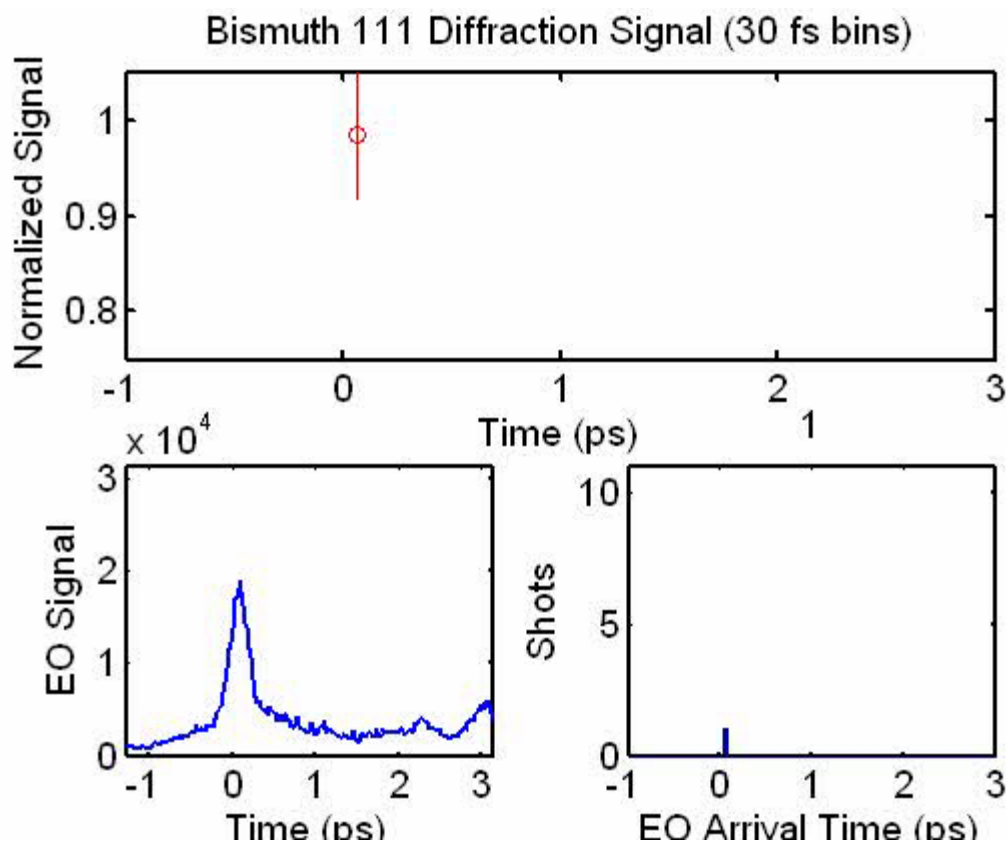
(Typical) Single-Shot EOS Data at SPPS (100 μ m ZnTe)



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Using the jitter @ SPPS for Random Sampling



D. M. Fritz *et al.* Preliminary Results

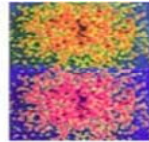
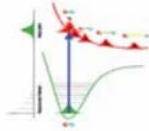
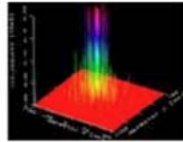
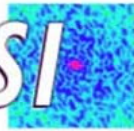
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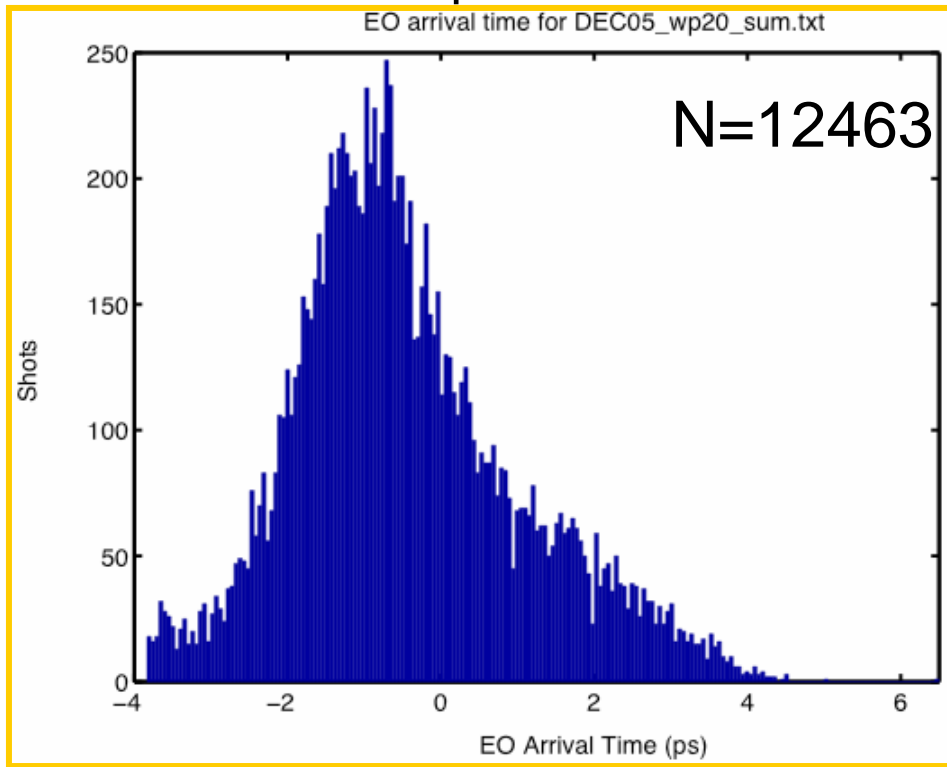
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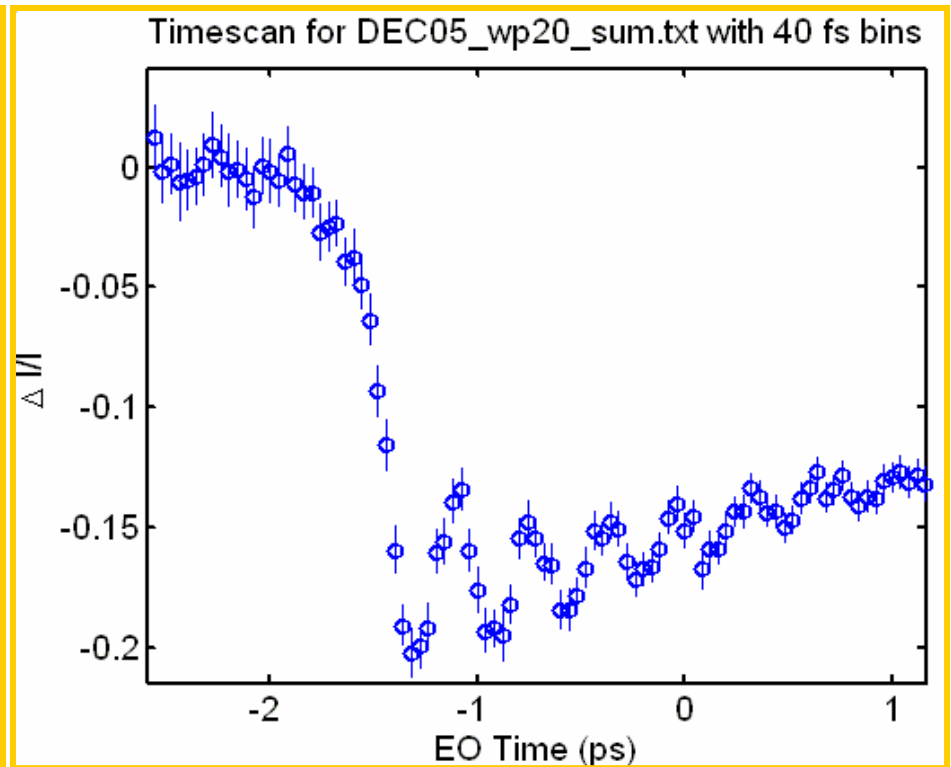
Using the jitter @ SPPS for Random Sampling

1.74 mJ/cm² (absorbed), $\langle n \rangle \sim 1\%$
 $\langle \Delta x \rangle = 5\text{pm}$

$f = 2.5\text{ THz}^*$ $A = 0.92\text{ pm}$



Arrival time distribution



Sorted normalized data

D. M. Fritz *et al.* Preliminary Results

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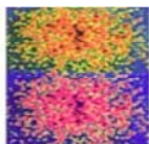
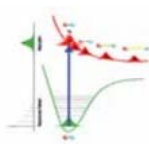
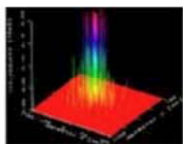
*precise time calibration still in progress

J. B. Hastings

jbh@slac.stanford.edu

Stanford
Linear
Accelerator
Center

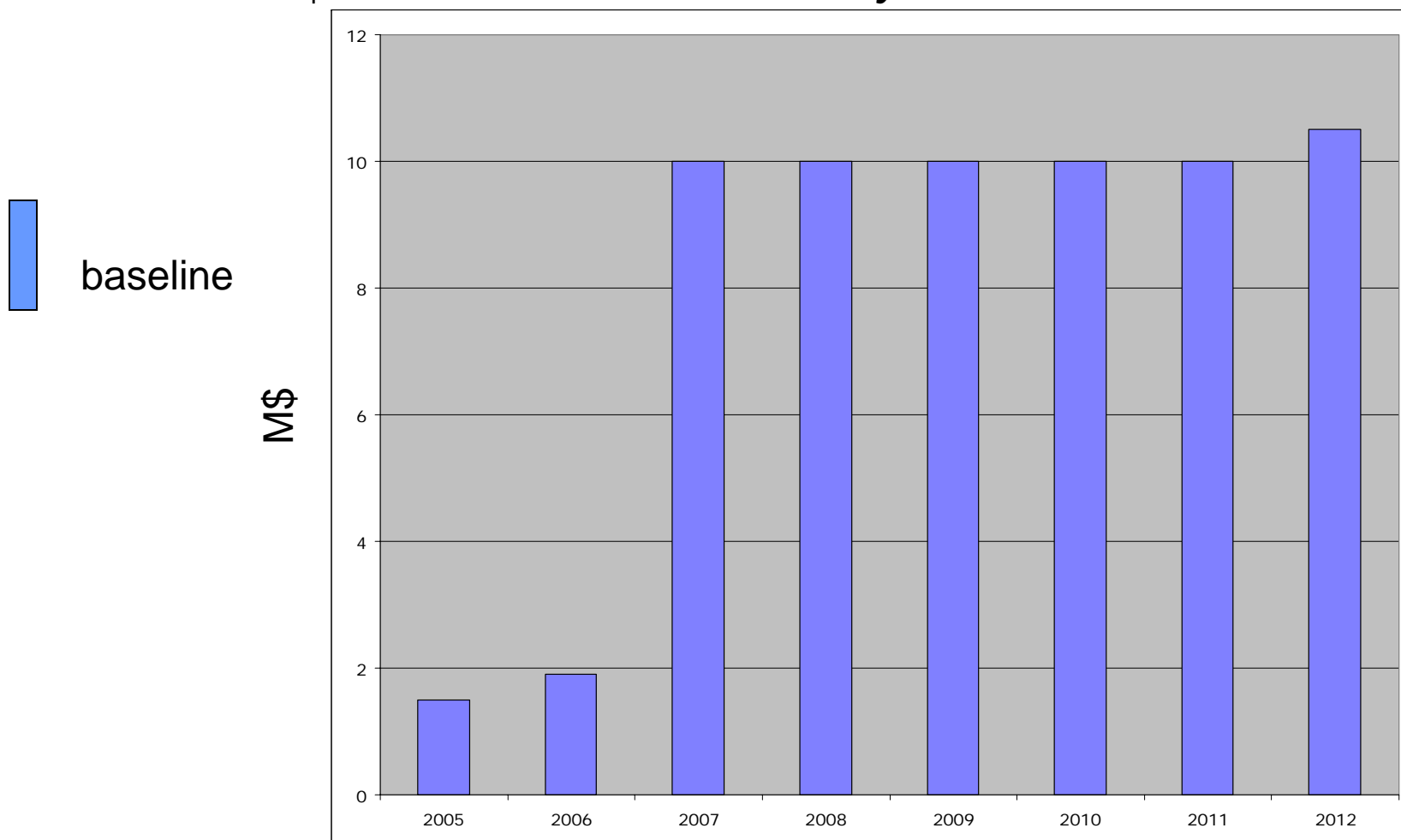




Current project funding profile

Total = ~\$64M

DOE has already increased FY2007 from 8-10 M\$

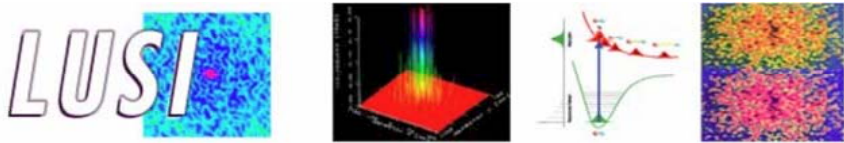


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Fiscal Year

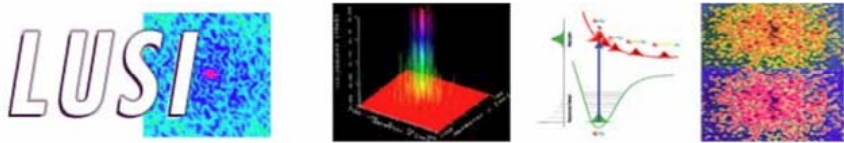
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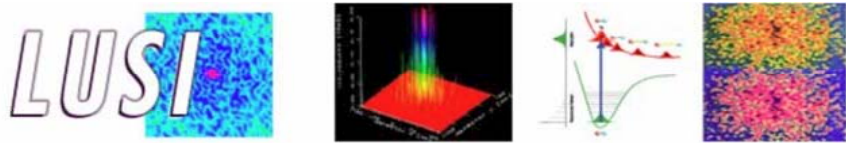
LUSI Phased Approach (1)

- First LCLS light may come in mid-2008
- Budget will not support building 4 instruments by 2008
- An approach to phased construction
 - Begin 2 instruments in phase 1
 - *sufficient functionality by mid-2008 to begin experiments*
 - *phase 1 instruments can support early work in all four areas*
 - *complete phase 1 while phase 2 is ramping up*
 - remaining instruments in phase 2
 - *begin phase 2 after 2008*
 - complete all work in 2012



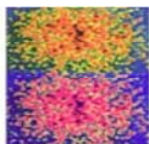
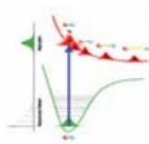
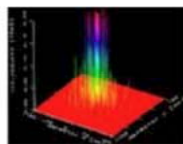
LUSI Phased Approach (2)

- First LCLS light may come in mid-2008
- Budget will not support building 4 instruments by 2008
- An approach to phased construction
 - Begin all instruments
 - *sufficient functionality by mid-2008 to begin experiments*
 - *carry out R&D as necessary for instrument construction*
 - *instrumentation in place early can support early work in all four areas*
 - complete all work in 2012



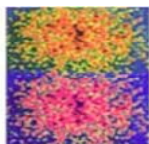
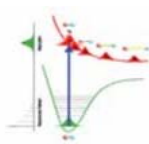
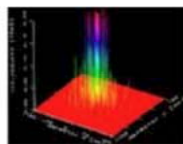
LUSI Phased Approach Summary

- First LCLS light may come in mid-2008
- Approach to take will be decided by
 - Develop schedules for all instruments separately
 - Develop R&D plan through first experiments up to 2012
 - Integrate the above-look at cost/schedule
 - Make choices based on scientific priorities
- Results of analysis may be either 2 instruments in each of 2 phases (approach (1)) or start all at the same time (approach (2)) and finish together

The logo for the Linac User Support Initiative (LUSI) features the word "LUSI" in a stylized, white, sans-serif font with a slight shadow effect, positioned over a blue and white abstract background.

Acceleration of LUSI funding profile

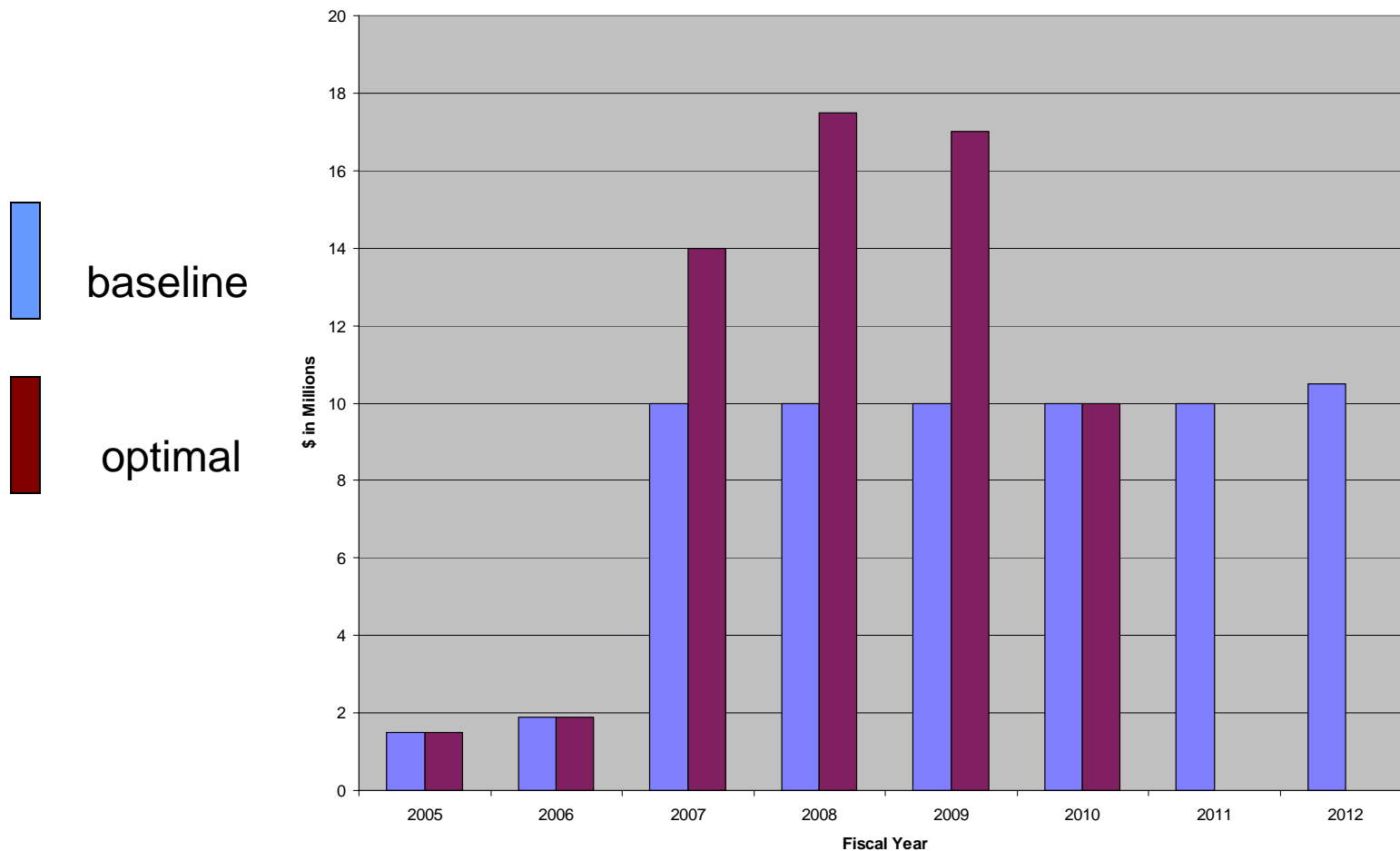
- Early completion will enable experience on all experiments to permit the expansion choices (next undulator specifications) to be strongly science based. The Japanese SCSS and European XFEL will have multiple sources at turn-on in ~2010 and ~2012 respectively. A 2012 LUSI CD-4 would be a disadvantage relative to the 2nd undulator and competitiveness.
- Earliest completion of LUSI will be most cost effective since all scientific staff needs to be on board early for the CDR and a phased approach.
- By the end of calendar 2006 (into FY07), LUSI will be ready for a significant number of the component procurements and could meet an accelerated schedule.
- To design and build the most effective diagnostics, it is important to have experiments to feedback to the developments. For example, with SPPS - timing depended critically on having the non-thermal melting experiment to determine the cross correlation of EO electron beam and the x-ray pulse arrivals. Earliest completion of LUSI will be significantly facilitating in this regard.
- Early funding (more aggressive funding profile) will facilitate most effective inclusion into LUSI of two experiment related items that have been de-scoped from LCLS (x-ray streak camera and 'flipper' mirrors).



Optimal project funding profile

Total = ~\$64M

DOE has already increased FY2007 from 8-10 M\$

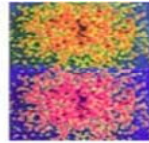
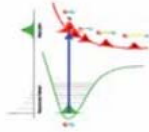
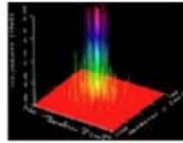
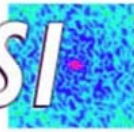


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J. B. Hastings
jbh@slac.stanford.edu

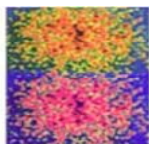
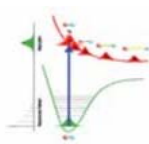
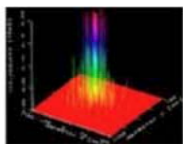


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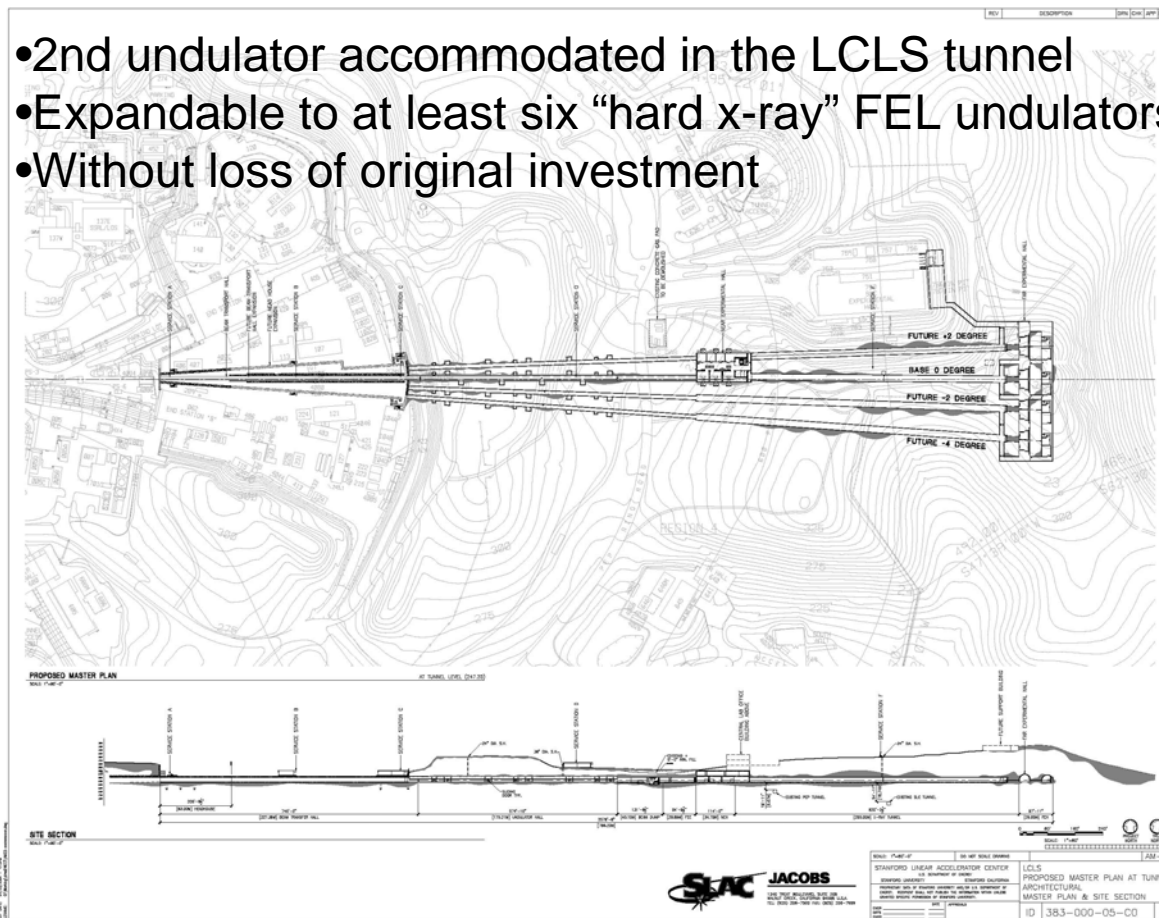
LUSI Scope

- Build instruments for hard x-rays that address 3 Thrust Areas: X-ray pump-probe, XPCS, Coherent x-ray imaging
- *Include one additional instrument, to address the soft-x-ray portions of pump-probe and coherent imaging Thrust Areas*
- Detector development



LCLS Design Permits Expansion

- 2nd undulator accommodated in the LCLS tunnel
- Expandable to at least six “hard x-ray” FEL undulators
- Without loss of original investment

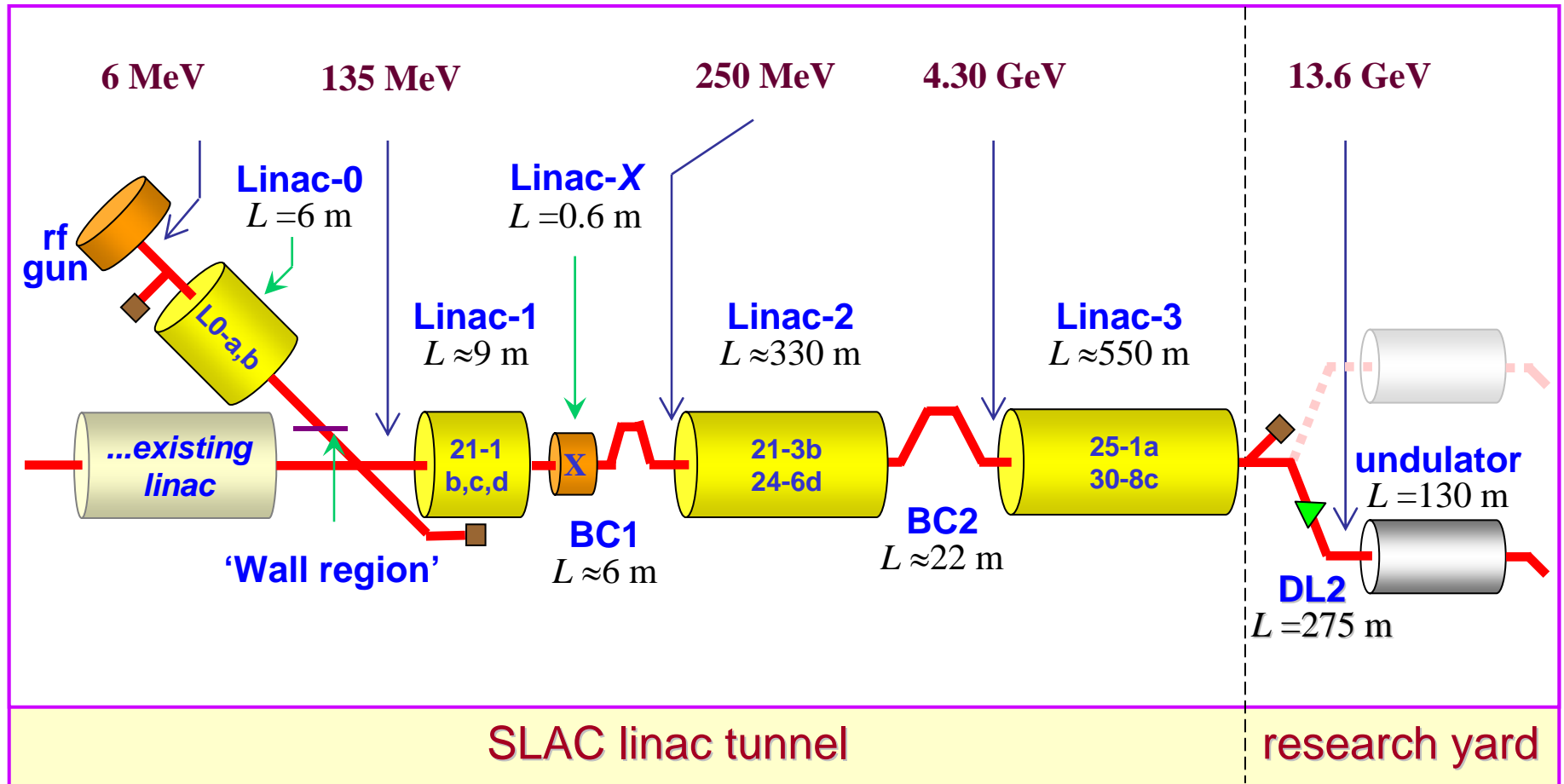
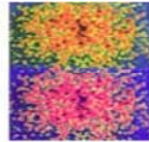
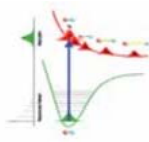
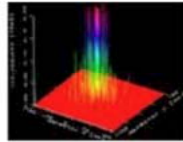
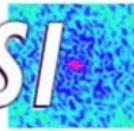


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J. B. Hastings
jbh@slac.stanford.edu



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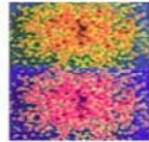
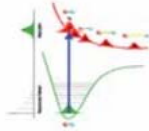
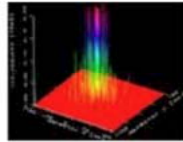
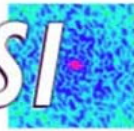


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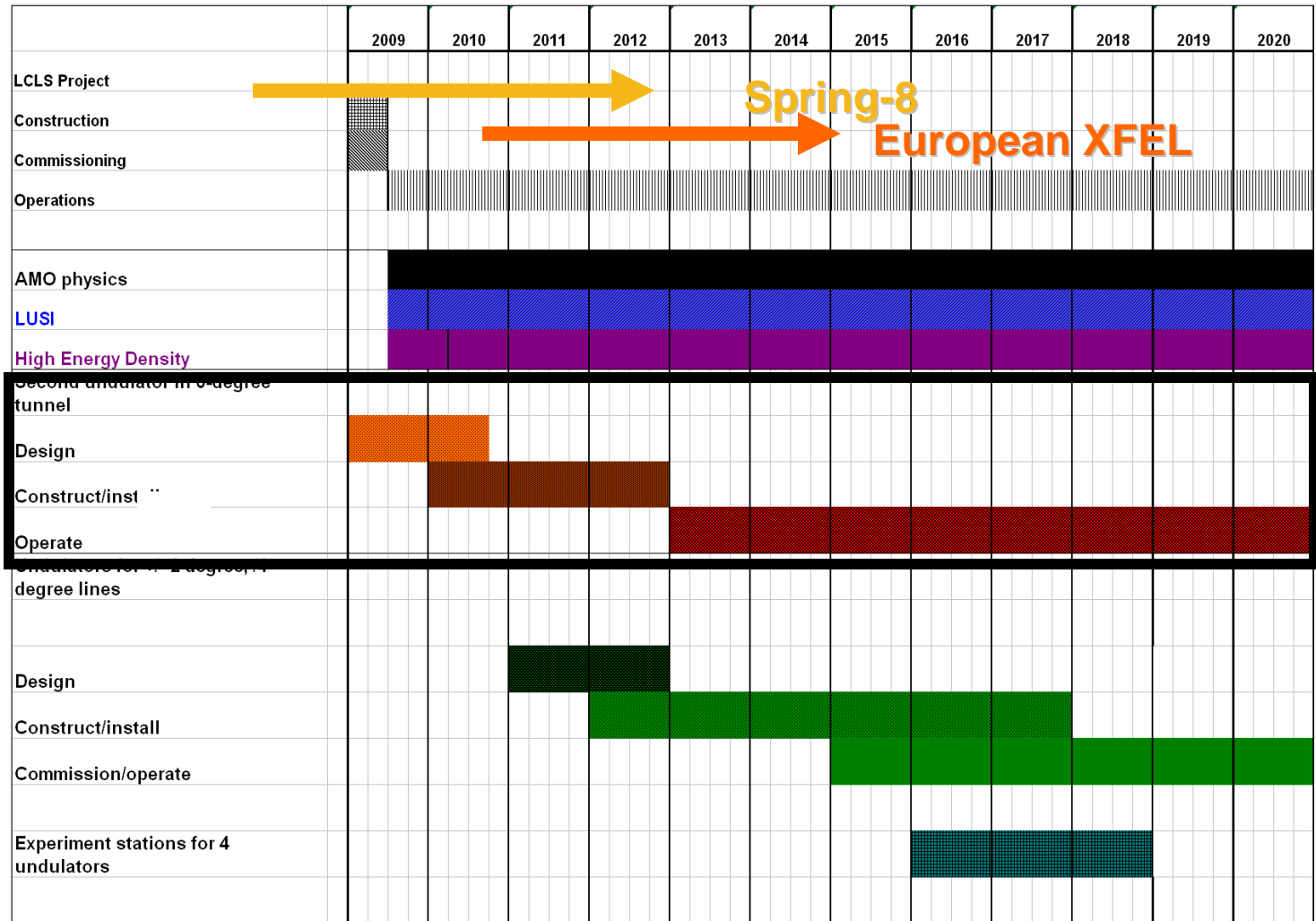
J. B. Hastings
jbh@slac.stanford.edu



LUSI



Looking Ahead – LCLS development



Spring-8
European XFEL

2nd Undulator
0 degree tunnel
(existing)

- design
- construct/
operate

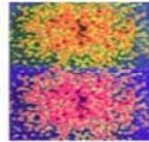
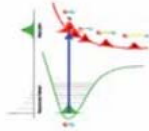
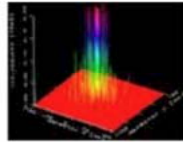
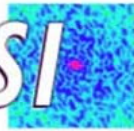
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J. B. Hastings
jbh@slac.stanford.edu



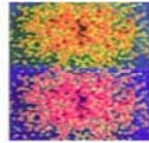
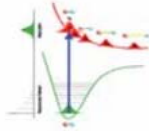
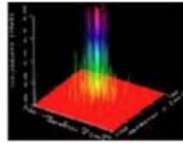
LUSI



Soft x-ray instruments

- Need science driven decision on the ‘next’ undulator
- Soft x-ray science opportunities can be explored with the baseline LCLS
- SAC Advice
 - Option 1: Build just a monochromator
 - Option 2: Provide rank ordered list of the proposed instruments

LUSI



LUSI Summary

- LUSI is on schedule now but *needs to pick up the pace*
- Will build 4 unique instruments, plus R&D on detectors, diagnostics and timing
- The next year will be very interesting