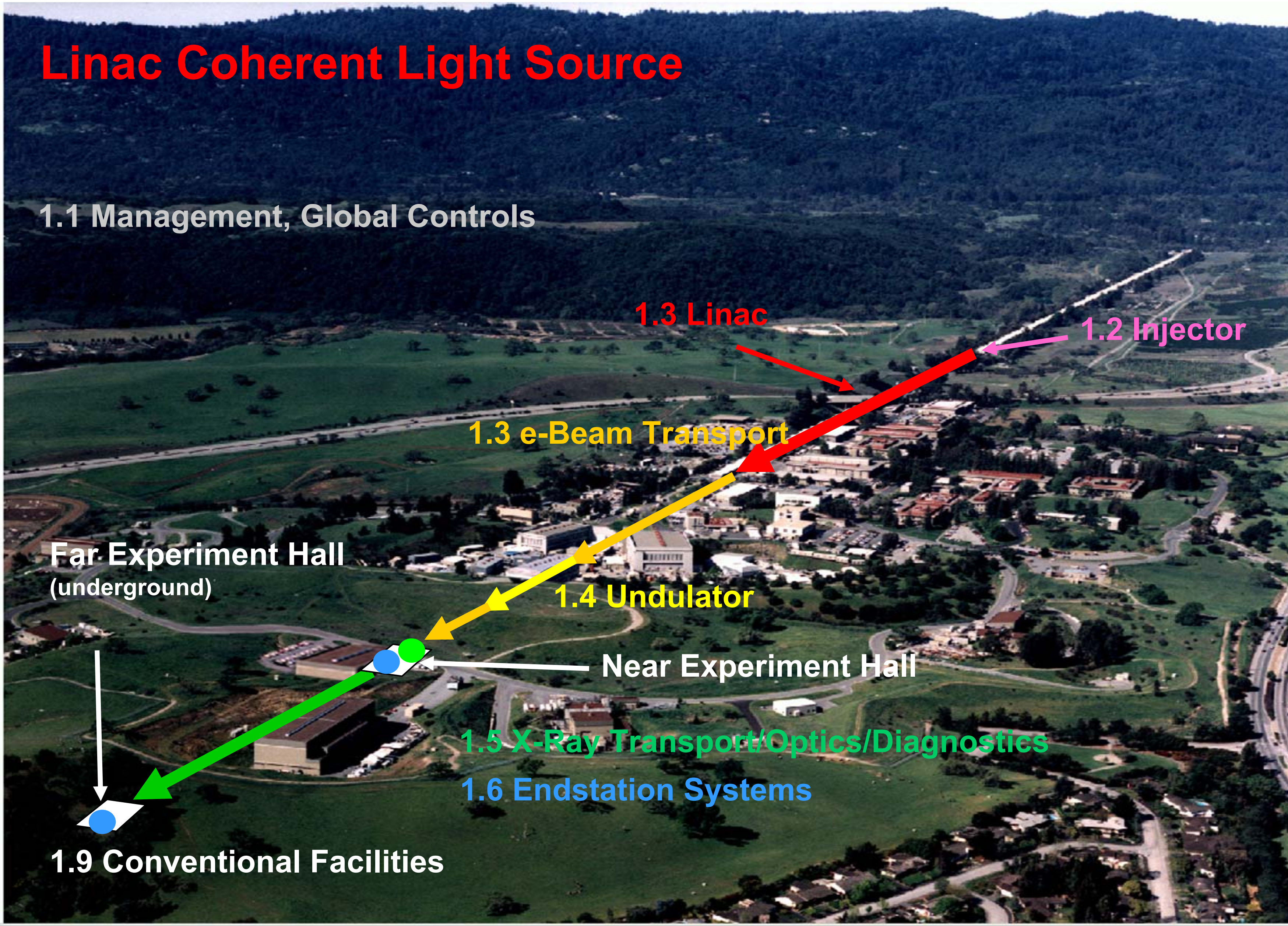
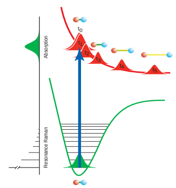
Linac Coherent Light Source

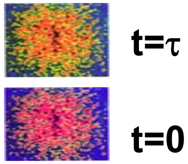


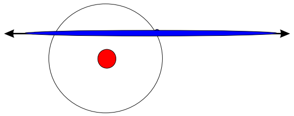
- Presented to BESAC 10-Oct-2000
- Critical Decision 0 approved 13-June 2001

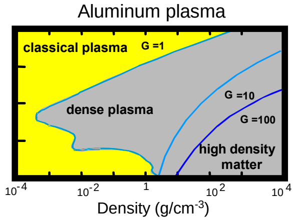
Program developed by international team of scientists working with accelerator and laser physics communities

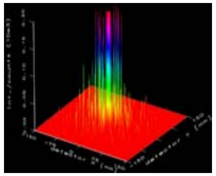
“the beginning.... not the end”

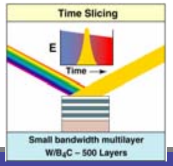












Femtochemistry

Nanoscale Dynamics in Condensed matter

Atomic Physics

Plasma and Warm Dense Matter

Structural Studies on Single Particles and Biomolecules

FEL Science/Technology

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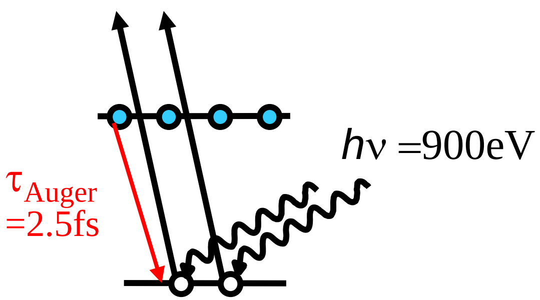
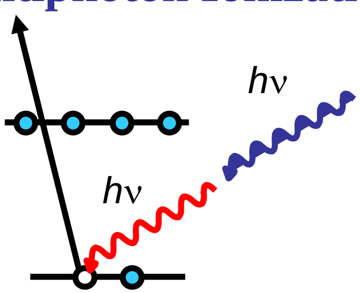
LCLS applications: *Atomic Physics*

Most basic LCLS experiments, aimed at understanding the physics of interaction of intense, ultra-fast pulse with atoms

Formation of Hollow Atoms:



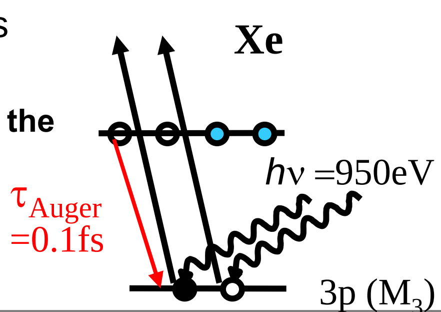
Multiphoton Ionization:



Giant Coulomb explosions of Xe clusters

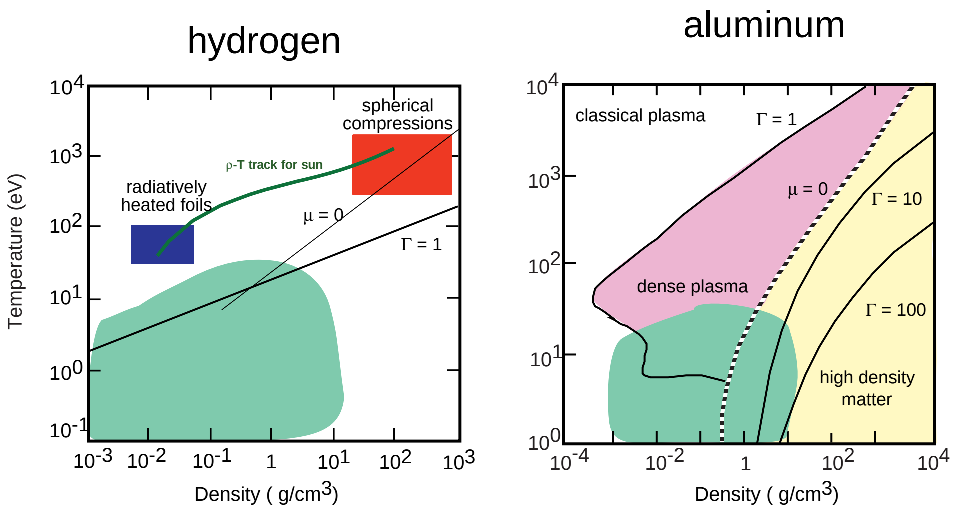
10^9 atoms

Understanding is central to the imaging of biomolecules



LCLS applications: *Studies of Warm Dense Matter*

"...that part of the density-temperature phase space where the standard theories of condensed matter physics and/or plasma statistical physics are invalid."



Γ = ratio between electric and thermal potential energy
μ = chemical potential (atom interaction potential)

Astrophysical and weapons-related studies lie in the area of warm dense matter. Largest uncertainties in many applied research areas of chemistry and physics come in the warm dense regime

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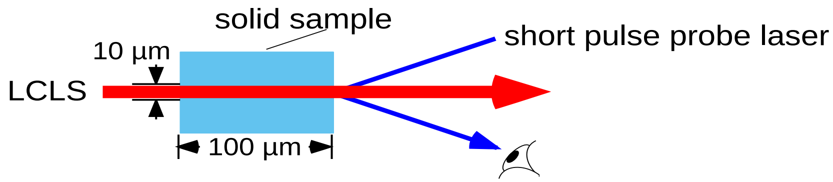
Studies of Warm Dense Matter

LCLS will be able, for the first time, to probe the warm dense matter regime. Use LCLS to create warm dense matter state and also (via delayed pulse) to probe it using x-ray scattering or imaging.

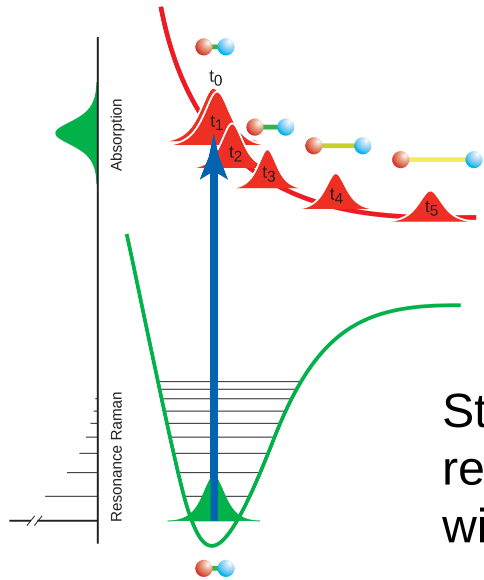
- **Creating Warm Dense Matter**
  - **Generate ≤10 eV solid density matter**
  - **Measure the fundamental nature of the matter via equation of state**



- **Probing resonances in HDM**
  - **Measure kinetics process, redistribution rates, kinetic models**
  - **All time scales**

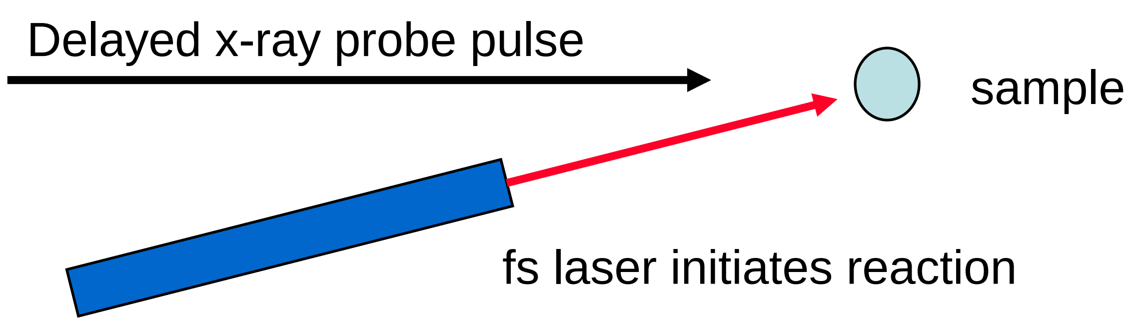
LCLS applications: *Femtosecond Chemistry*

X-ray FEL offers the ability to follow the motions of atoms on a femtosecond time scale



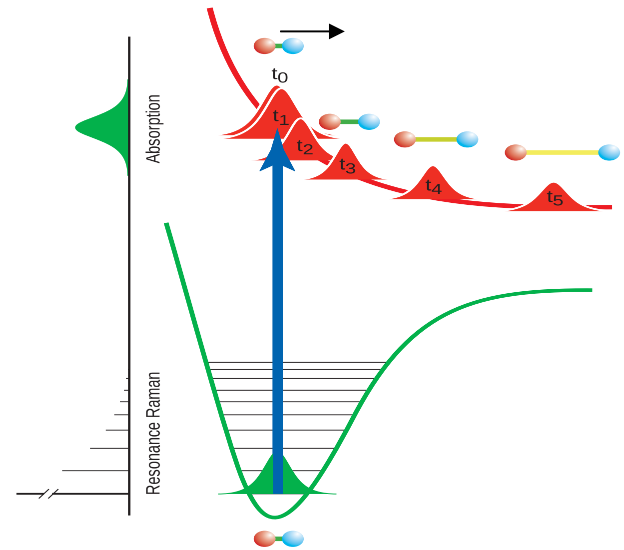
Studies of small system reactions can be compared with theory

Combine single-pulse x-ray diffraction with fast laser excitation



Femtosecond Chemistry

Lasers probe charge dynamics
Electron Diffraction limited to ps range
LCLS will probe 200 ⟶ 10 fs range
Chemical dynamics happens in fs - ps range



$H_2O \rightarrow OH + H$
about **10 fs**

time depends on mass

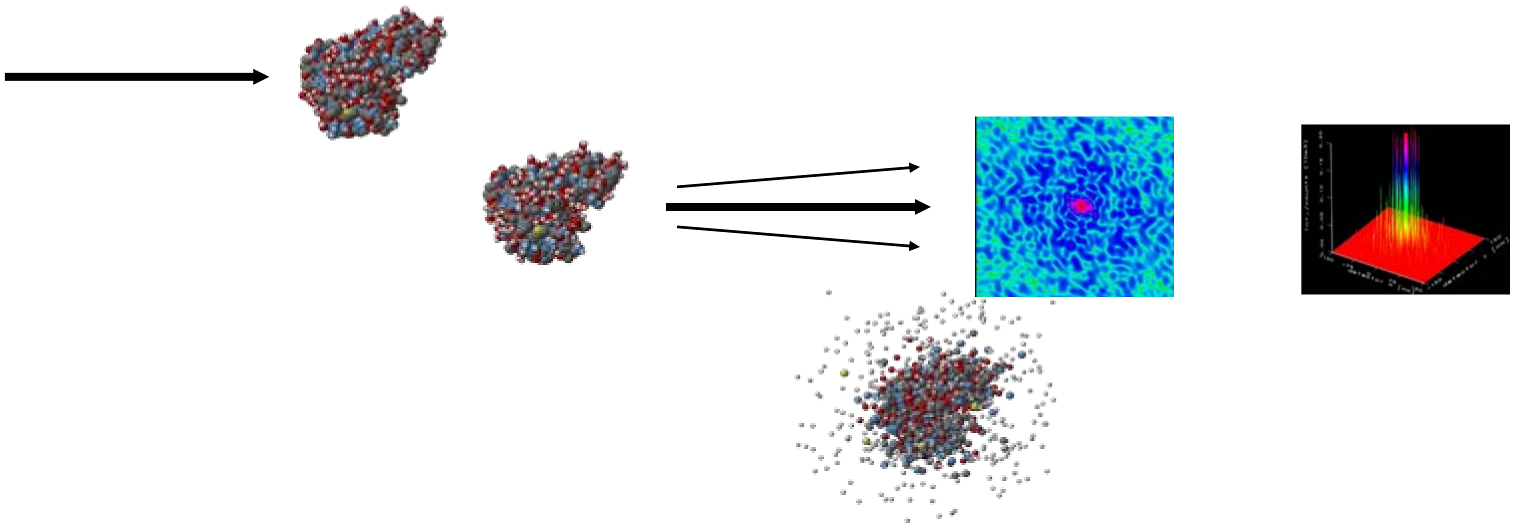
$CH_2I_2 \rightarrow CH_2I + I$
about **100 fs**

LCLS applications:

X-Ray Diffraction from a Single Protein Molecule

Avoids radiation damage problem by taking diffraction data before damage occurs

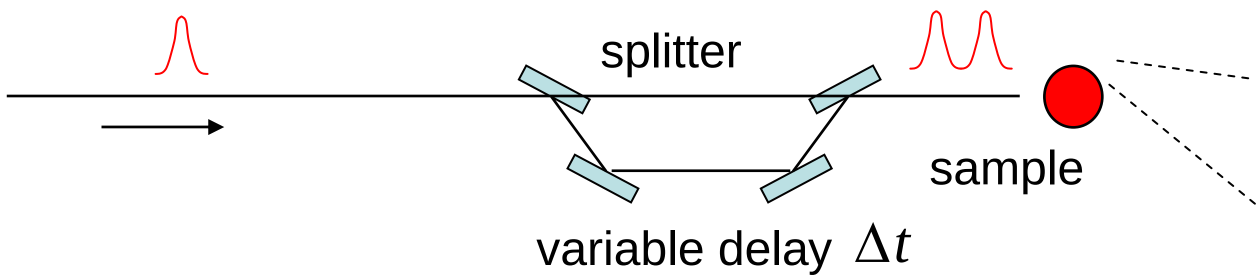
Would allow much broader range of biological structures to be determined

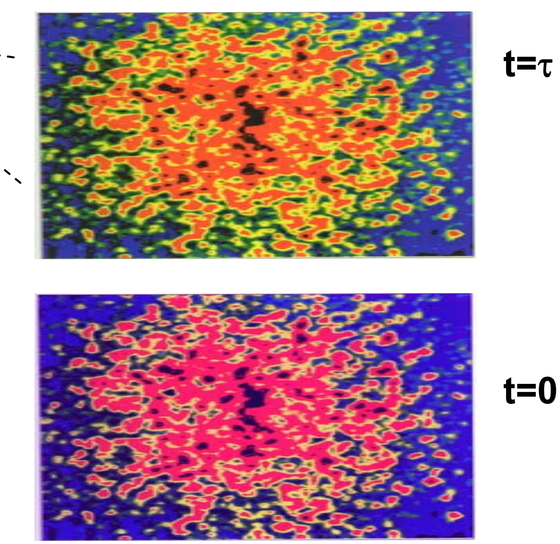


LCLS applications: *Nanoscale Dynamics in Condensed Matter*

Look at dynamics in solids and liquids on ps time scale

In **picoseconds - milliseconds** range





Analyze contrast
as f(delay time)

Letters of Intent

- Types
  - Category A: Complete Endstation
  - Category B: Specific Science Goals
  - Category C: Technical Innovations
- Response
  - Total of 32 received
  - 256 Independent investigators
  - 91 Institutions

LCLS SAC Response

- Identified 5 Thrust Areas
  - Atomic Molecular and Optical Physics
  - Pump/probe high-energy-density (HED) physics
  - Nano-particle and single molecule (non-periodic) imaging
  - Pump/probe diffraction dynamics
  - Coherent scattering at the nanoscale

First Experiments-SAC Response

SLAC Report 611

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

Femtochemistry	***Pump/probe diffraction dynamics***
Nanoscale Dynamics in Condensed matter	***Coherent scattering at the nanoscale***
Atomic Physics	***Atomic Molecular and Optical Physics***
Plasma and Warm Dense Matter	***Pump/probe high-energy-density (HED) physics***
Structural Studies on Single Particles and Biomolecules	***Nano-particle and single molecule (non-periodic) imaging***
FEL Science/Technology	

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LCLS SAC Response (cont'd)

- All LoI's were reviewed and fit into thrust areas
- Supported Short pulse (beyond baseline) R&D
  - Will enable new science
- LCLS efforts in AMO and detector development (endstation systems) important for early turn on

User workshop held in Fall 2004

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The way forward:
Major Item of Equipment

- Funded thru BES
- Science community develops the science case
- The project engineering and management is the responsibility of SLAC/SSRL
- Full rigor of DoE review is in place
- Insures compatibility, common design, ease of maintenance

MIE Cont’d

Team Responsibilities

- Thrust area teams responsible for the science
- Thrust area teams provide the specifications for the instruments
- Collaborate on the conceptual design
- As appropriate given responsibility for construction of specific components

LCLS Science Thrust Areas

- Atomic, Molecular, and Optical (AMO) science
- High-energy-density (HED) science
- Diffraction studies of stimulated dynamics
- Coherent-scattering studies of nanoscale fluctuations
- Nano-particle and single-molecule (non-periodic) imaging

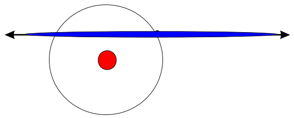
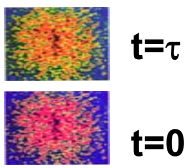
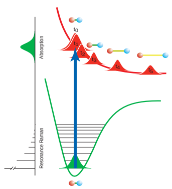
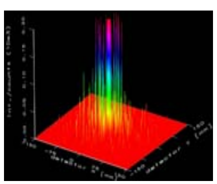
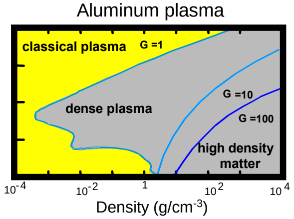
BES approach to the Thrust Areas

- AMO science will be included in LCLS construction project
- HED science deemed to be outside the mission of BES

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

LUSI and LCLS Science

		team leader	co-team leader(s)
	• AMO science	Lou Dimauro	Nora Berrah
	• Coherent scattering of nanoscale fluctuations	Brian Stephenson	Karl Ludwig Gerhard Grübel
	• Diffraction studies of stimulated dynamics (pump-probe)	Kelly Gaffney	David Reis Jörgen Larsson T. Tschentscher Anders Nilsson
	• Nano-particle and single molecule (non-periodic) imaging	Janos Hajdu	Henry Chapman John Miao Jan Lüning
Aluminum plasma 	• High energy density science	Dick Lee	Phil Heimann

SLAC Report 611

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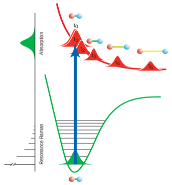
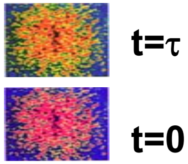
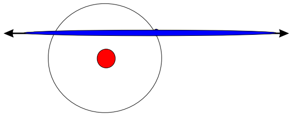
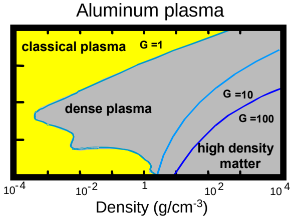
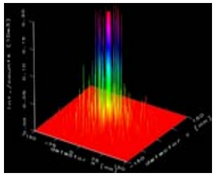
"the beginning.... not the end"











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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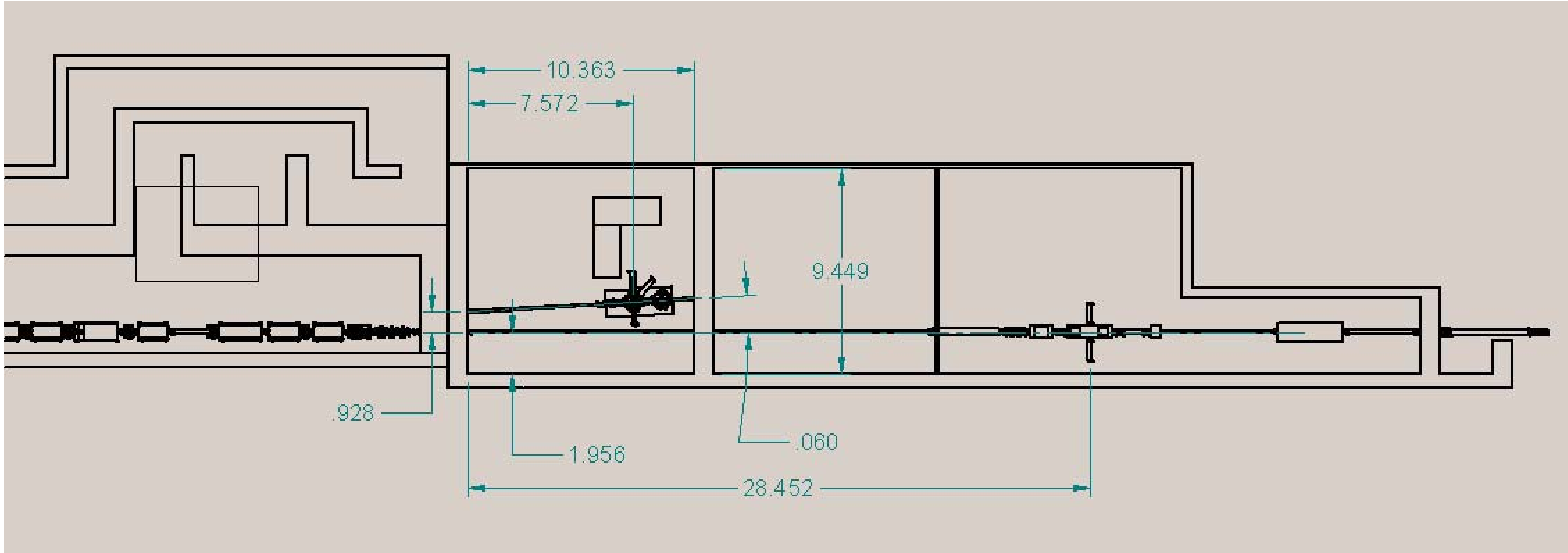
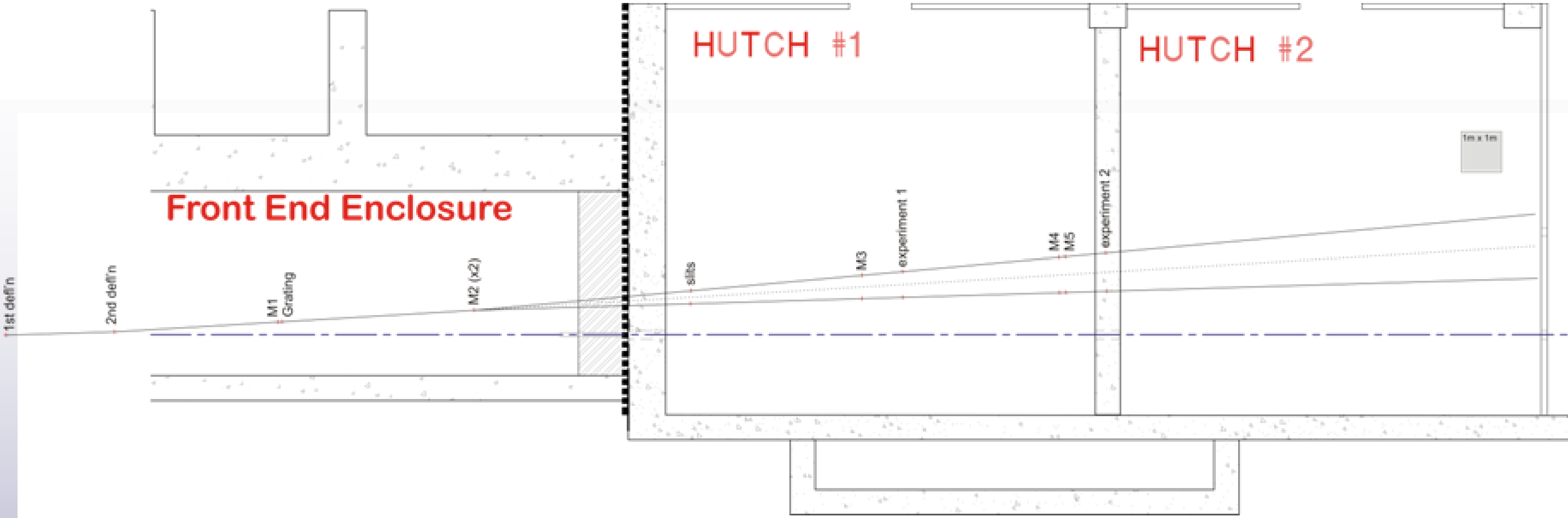
LUSI Scope

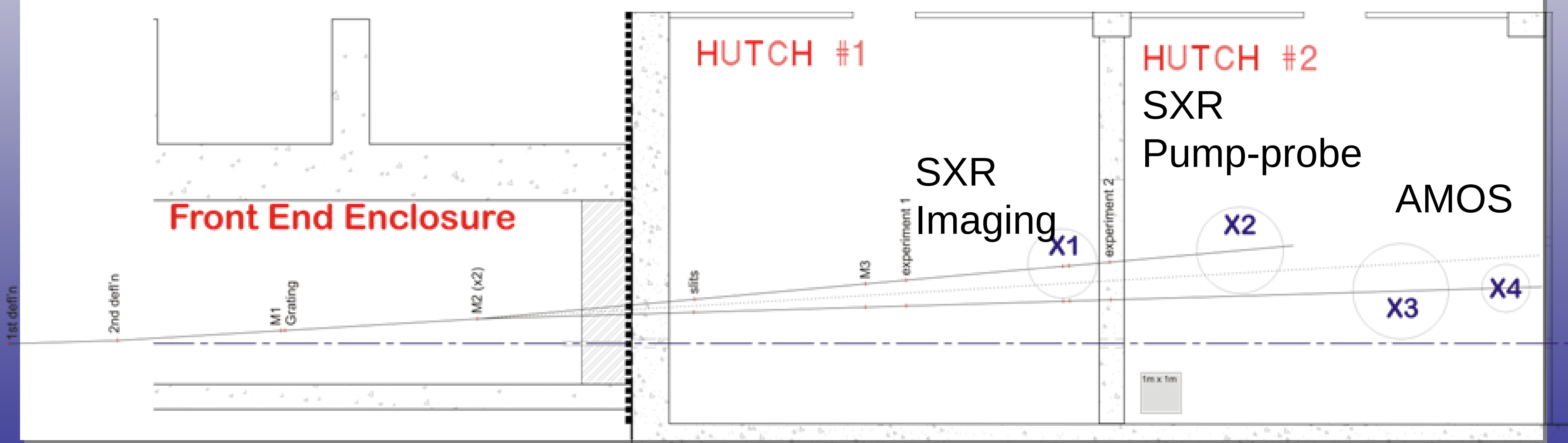
- Build instruments for hard x-rays that address 3 Thrust Areas:
  - X-ray pump-probe
  - XPCS
  - Coherent x-ray imaging
- Include one additional instrument, to address the soft-x-ray portions of pump-probe and coherent imaging Thrust Areas
- Detector development

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





Layout of NEH hutches with soft x-ray line



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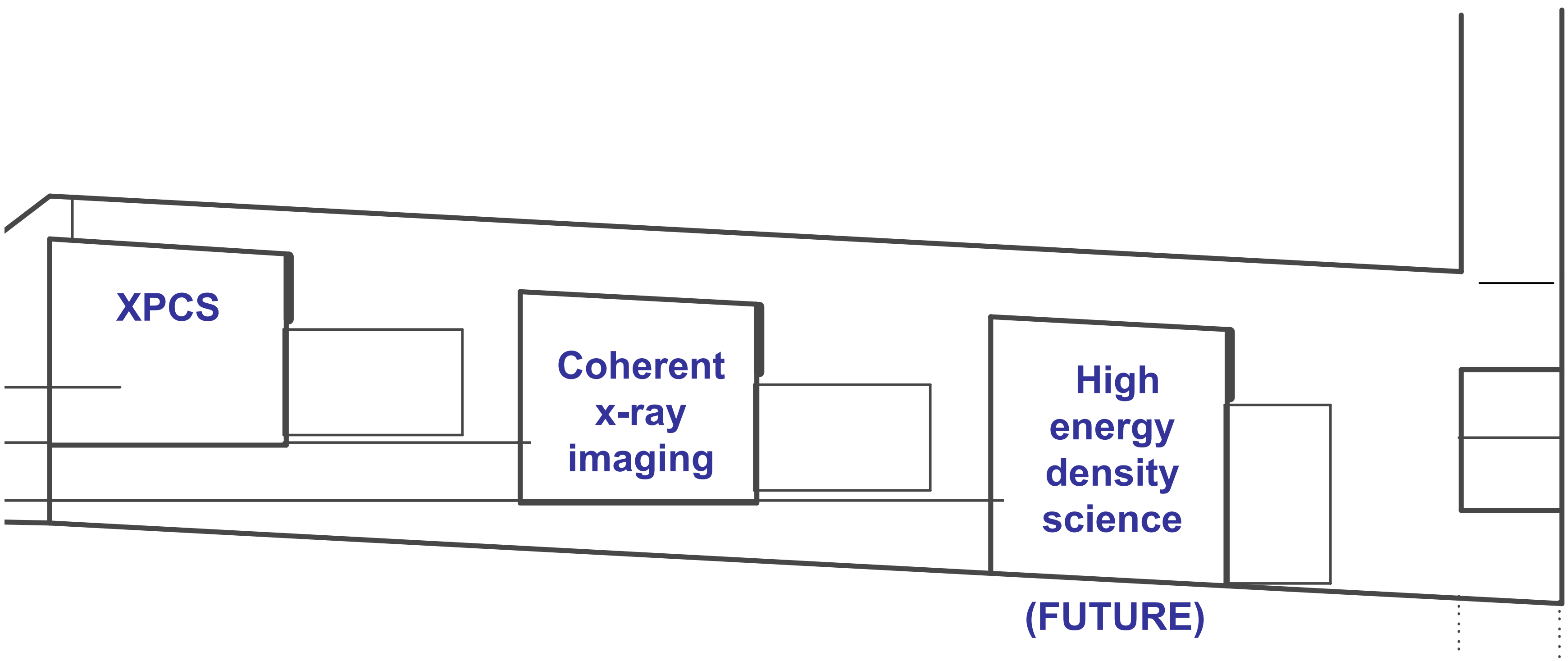
FEH


XPCS
Coherent x-ray imaging
High energy density science
(FUTURE)

Plans for FY2006

- Initial funding has been provided ($1.9M)
- Staff up
- Prepare CDR complete August 15
- Lehman review Sept. 13-14 for CD-1
- Continue design
- Additional reviews as needed

Technology needed for the science opportunities

- Detector development
  - 2d detectors
  - Streak camera
  - Ion-electron ToF: spatial and temporal resolution required
- Laser – x-ray timing
- Damage mitigation
- Diagnostics
  - Pulse length
  - Pulse energy
  - Pulse wavelength
- Novel x-ray optics
- **Data acquisition, visualization, storage**

Detector Development

- LCLS experiments need new detector technology
- Established LCLS Detector Advisory Committee to evaluate technology choices and monitor development
- Dual development strategy for fast 2-d detectors
- LCLS experiments can benefit from improvements of x-ray streak cameras.
- The streak camera can be a real aid in commissioning the x-ray split/delay.

LUSI Phased Approach

- First LCLS light may come in mid-2008
- Budget will not support building 4 instruments by 2008
- Proposed Instrument completion:
  - Coherent Imaging 2010
  - Pump-probe 2011
  - Soft x-ray and XPCS 2012 *note 2012 date determined by funding and detector delivery*