Linac Coherent Light Source (LCLS) at SLAC

Hamid Shoaee

for

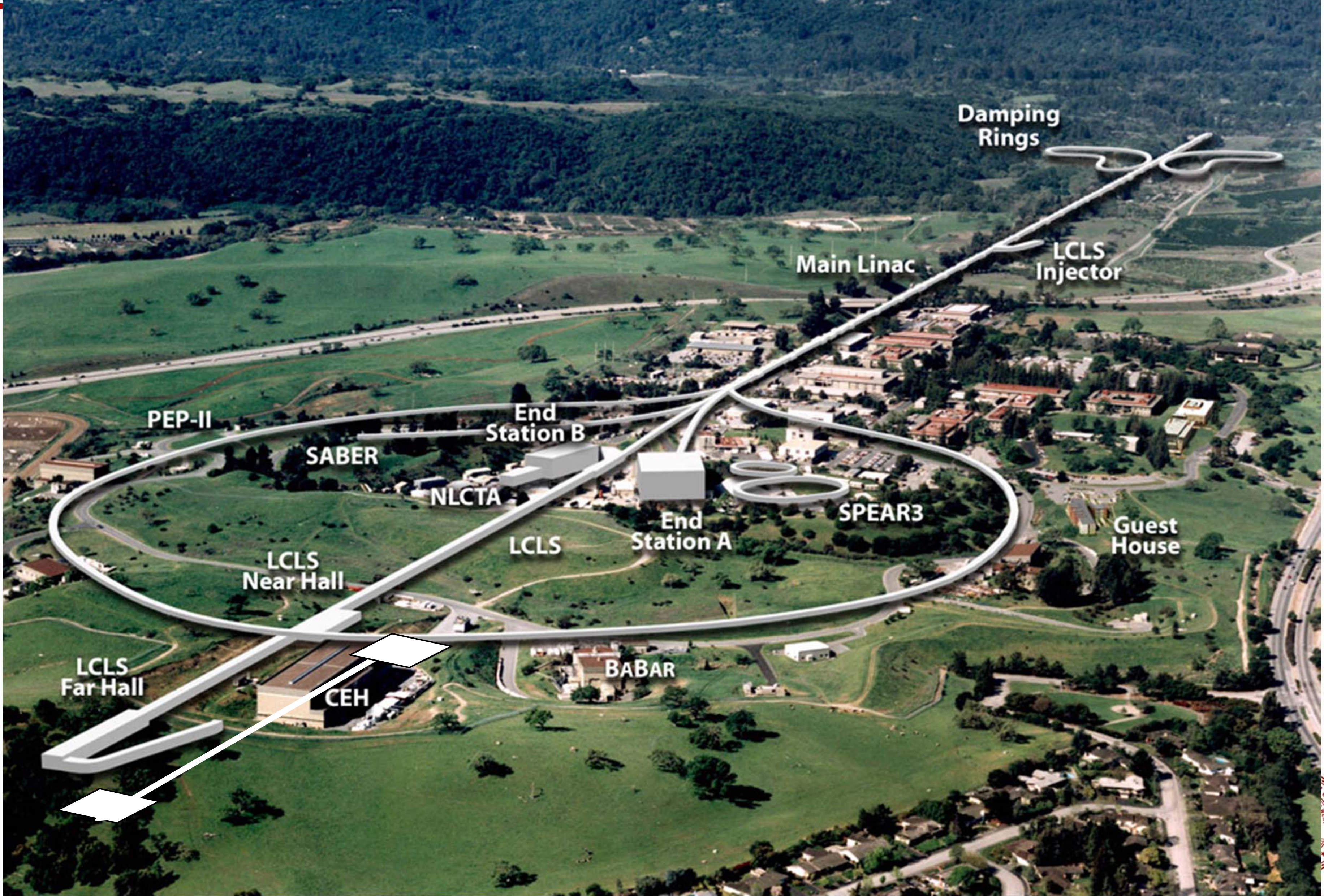
SLAC Controls Department

Outline

- LCLS-I
  - Facility Overview
  - Commissioning Success
  - Controls System Architecture
- Towards the Future
  - Overwhelming demand for LCLS-II
  - LCLS-II Proposal
  - R&D
  - Further into the future

Linac Coherent Light Source at SLAC

X-ray FEL uses last 1-km of existing 3-km linac



Linac Coherent Light Source at SLAC

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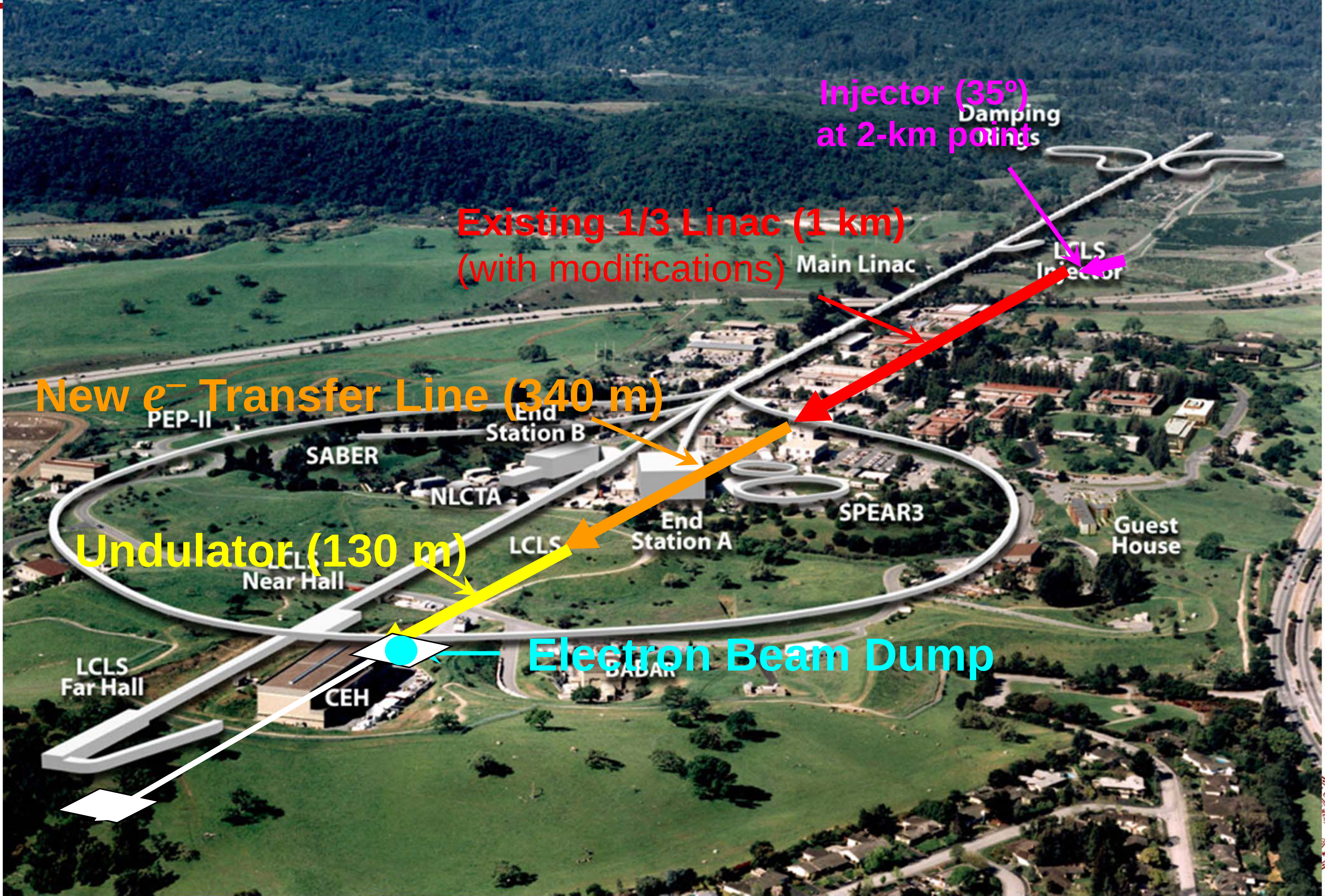
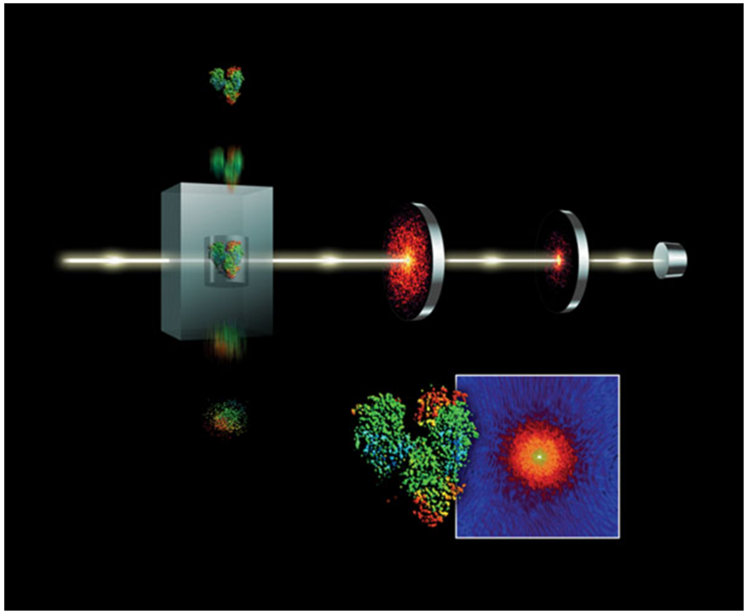
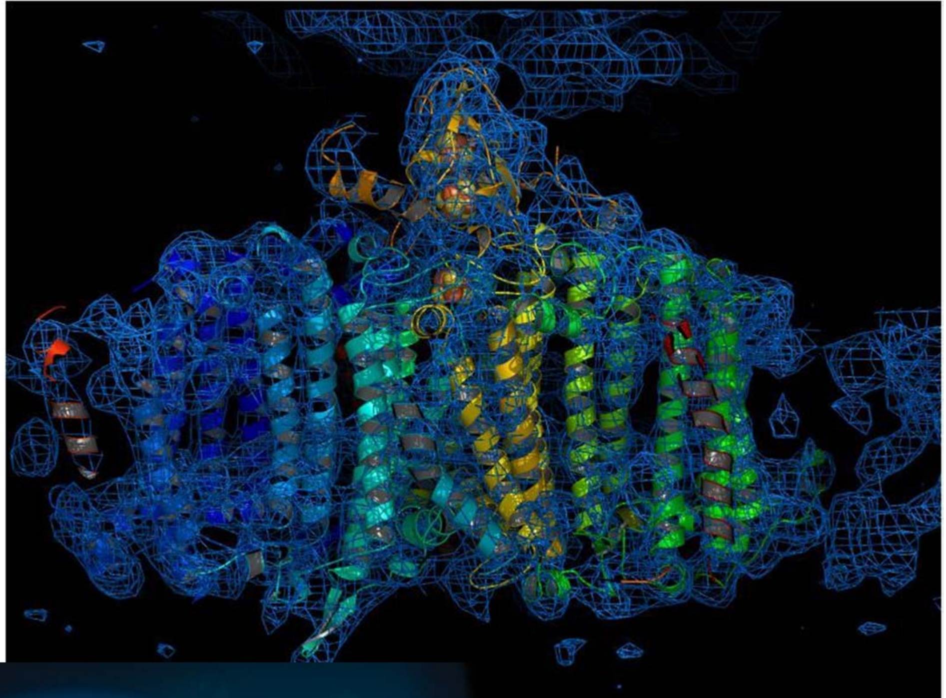


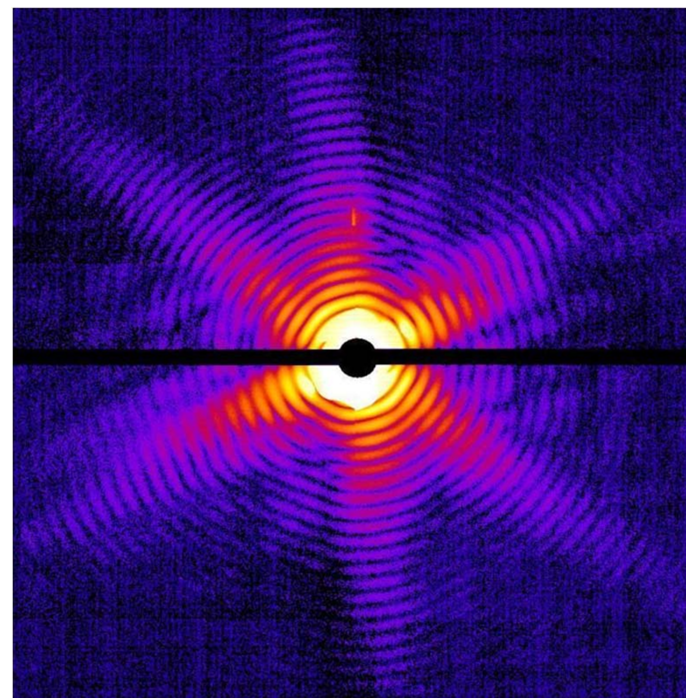
World's First Hard X-ray FEL

- A billion times brighter than previous sources
- < 2 Å & 50 femtoseconds
  - Study of ultra-fast and ultra-small phenomena
  - Can capture images of atoms and molecules in motion

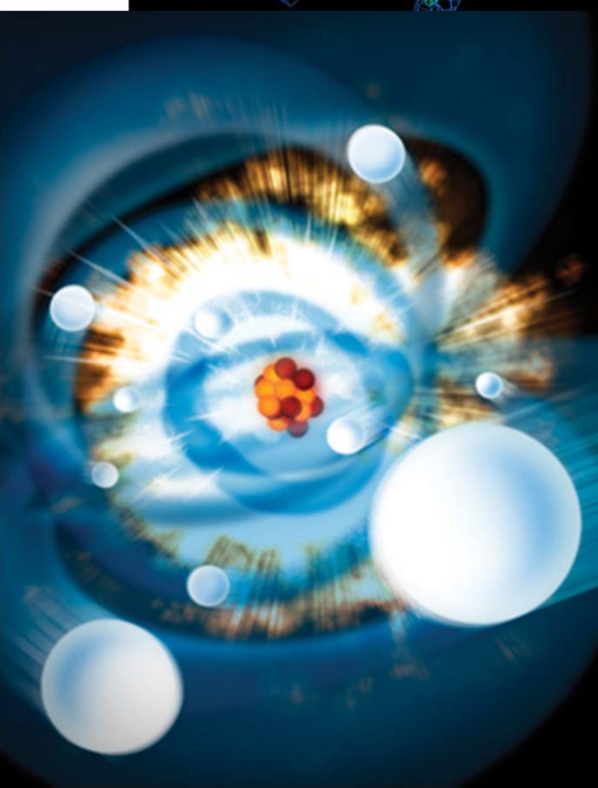




Photosystems I complex
(R. Fromme, ASU)

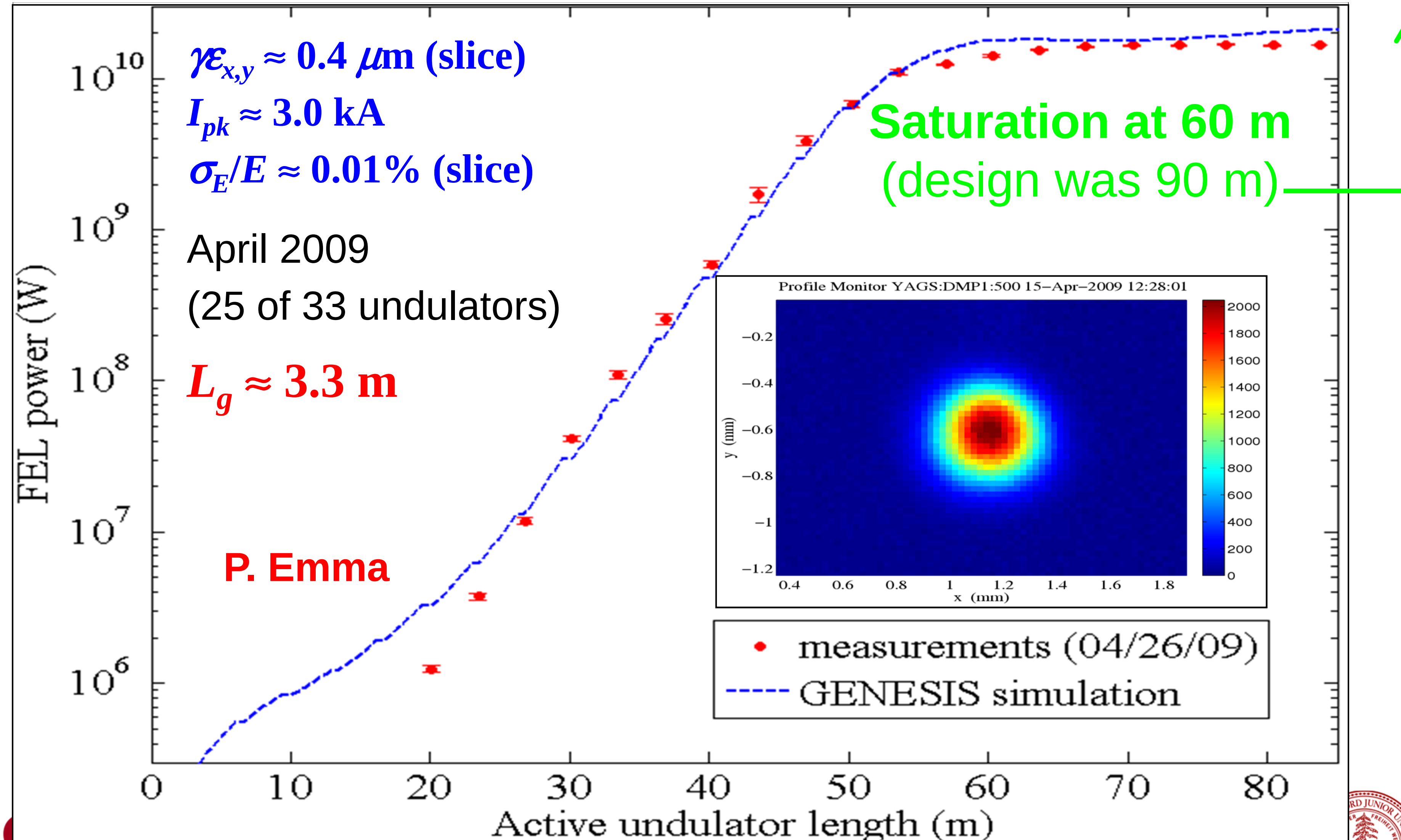


Single Mimivirus particle
(T. Ekeberg, Uppsala U.)



Fully-ionized Ne $^{10+}$
(Bozek , Bostedt)

LCLS Achieves FEL Saturation at 1.5A



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Beam saturates in 60m rather than 90m (25 of 33 undulators)

Gun brightness exceeds LCLS Goals

FEL is fully tunable: rep rate, pulse length, photon energy, peak power

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LCLS Machine Performance

	Baseline performance	**Current performance**
Photon energy range	830 to 8300 eV	**480 to 10,000 eV**
FEL pulse length	230 fs	**5 - 500 fs**
FEL pulse energy	up to 2 mJ	**up to 4 mJ**

- **Beam availability to users > 95%**
- **Controls uptime > 98% (goal = 98.8%)**
- **120 fs pump probe synchronization has been achieved**

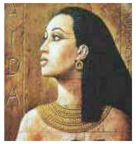
Commissioning Successes & Challenges

- Challenging combination of Legacy & EPICS
- EPICS-based Injector & drive laser 2007
- Legacy & EPICS Linac 2008
- BPMs & Magnets in EPICS 2009-2010
- Linac Upgrade to full EPICS 2010-2011
  - Transition critical functionality from VMS to Linux
  - Data bridge from CAMAC to VME IOCs

– **LCLS fully EPICS-based Early 2012**

AIDA – Accelerator Integrated Data Access

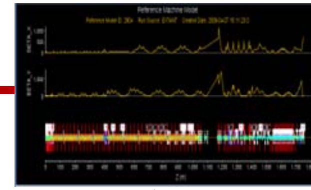
- A system for uniform access to controls infrastructure data
- Integrated data from Legacy & EPICS systems
- Complex Data in addition to individual controls points
- Data from remote machines made available to MATLAB & Java apps, in control room, or off site
- Data sources include machine, model, history, configuration, RDB, etc.
- Allows rapid physics applications development regardless of underlying legacy or EPICS controls
- Applications mostly unaffected by controls system upgrades

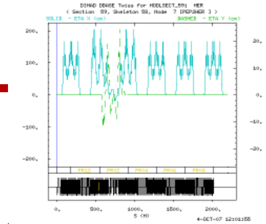


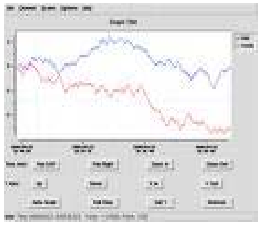
AIDA - Accelerator Integrated Data Access

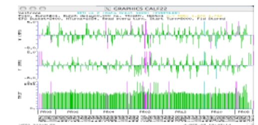
http://www.slac.stanford.edu/grp/cd/soft/aida/

AIDA is a Service Oriented Architecture for LCLS and other SLAC machines









INTEGRATES DIFFERENT CONTROL SYSTEMS

EPICS **Archiver**

SLC Controls

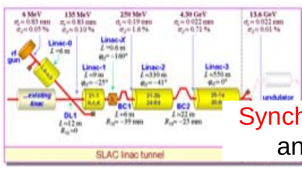
EPICS Controls

XAL Model

DIMAD Model

BPM Orbit dat

Arbitrary **Oracle** DB queries

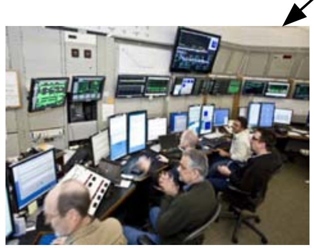


Synchronized **Magnet** and **RF** Control

AIDA Cloud

ABSTRACTS CONTROL VIEW TO PHYSICS VIEW

ALL KINDS OF DATA, NOT JUST CONTROLS



SINGLE, TRIVIAL USER INTERFACE TO ALL DATA

Control Room Physics Applications / Matlab

Scientist's own laptop / desktop

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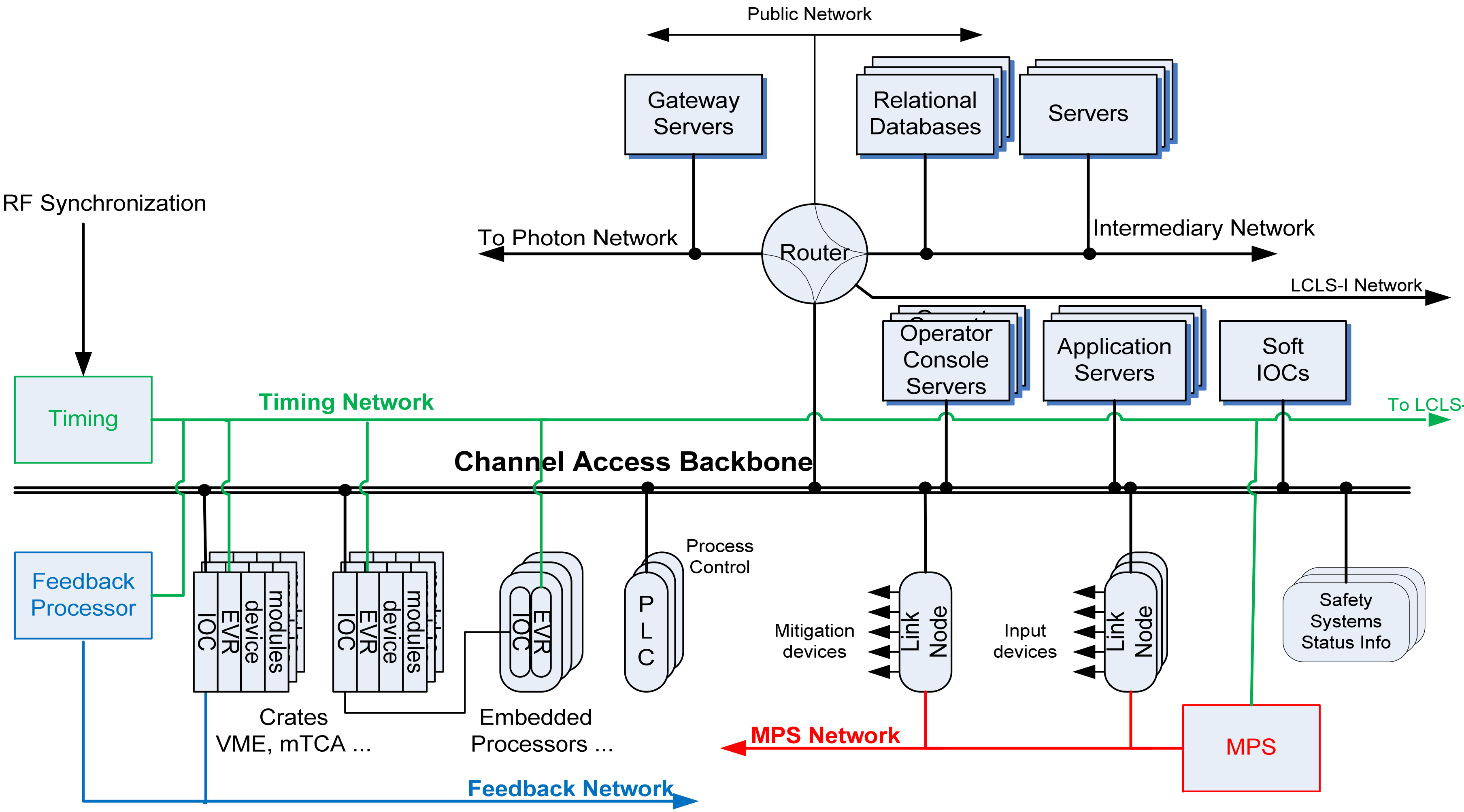
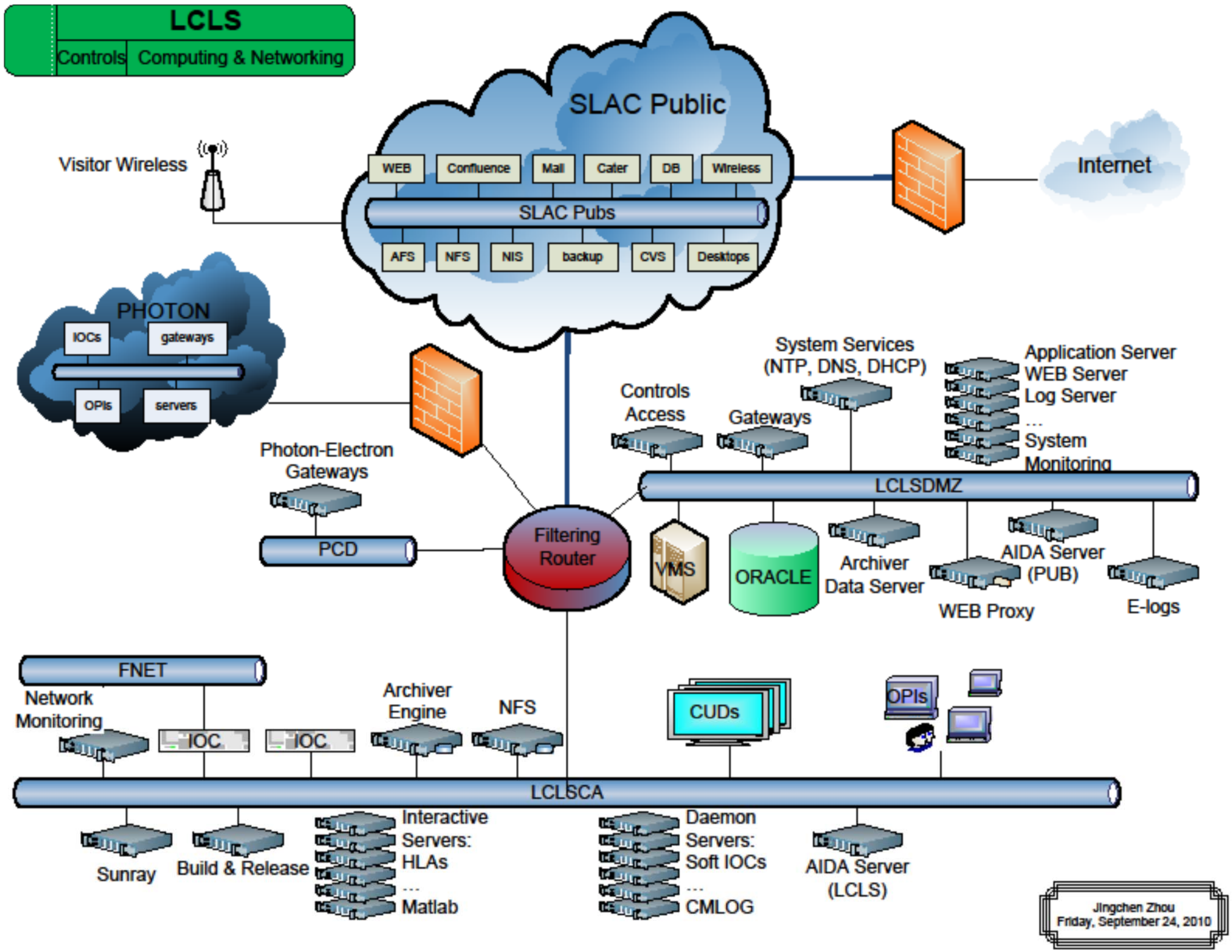
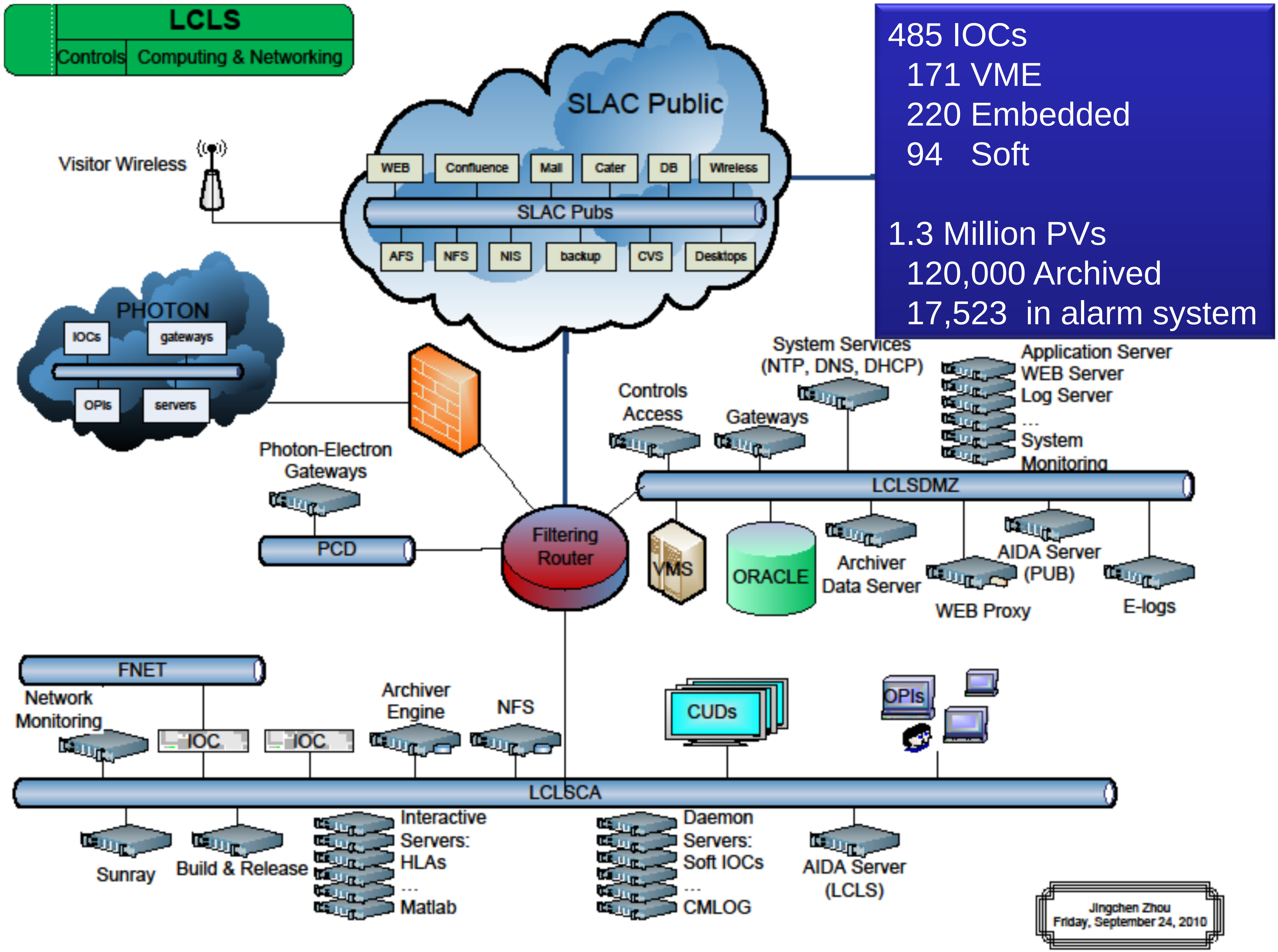
Authors: Greg White, Bob Hall, Bob Sass, George MacIntyre, Ron MacKenzie

LCLS 4-Layer Network Architecture




LCLS
Controls
Computing & Networking
SLAC Public
Visitor Wireless
WEB
Confluence
Mail
Cater
DB
Wireless
SLAC Pubs
AFS
NFS
NIS
backup
CVS
Desktops
Internet
PHOTON
IOCs
gateways
OPIs
servers
Photon-Electron Gateways
PCD
Filtering Router
Controls Access
Gateways
System Services (NTP, DNS, DHCP)
Application Server
WEB Server
Log Server
...
System Monitoring
LCLSDMZ
VMS
ORACLE
Archiver Data Server
AIDA Server (PUB)
WEB Proxy
E-logs
FNET
Network Monitoring
IOC
IOC
Archiver Engine
NFS
CUDs
OPIs
LCLSCA
Sunray
Build & Release
Interactive Servers:
HLAs
...
Matlab
Daemon Servers:
Soft IOCs
...
CMLOG
AIDA Server (LCLS)
Jingchen Zhou
Friday, September 24, 2010


LCLS
Controls
Computing & Networking
485 IOCs
171 VME
220 Embedded
94 Soft
1.3 Million PVs
120,000 Archived
17,523 in alarm system
SLAC Public
WEB
Confluence
Mail
Cater
DB
Wireless
SLAC Pubs
AFS
NFS
NIS
backup
CVS
Desktops
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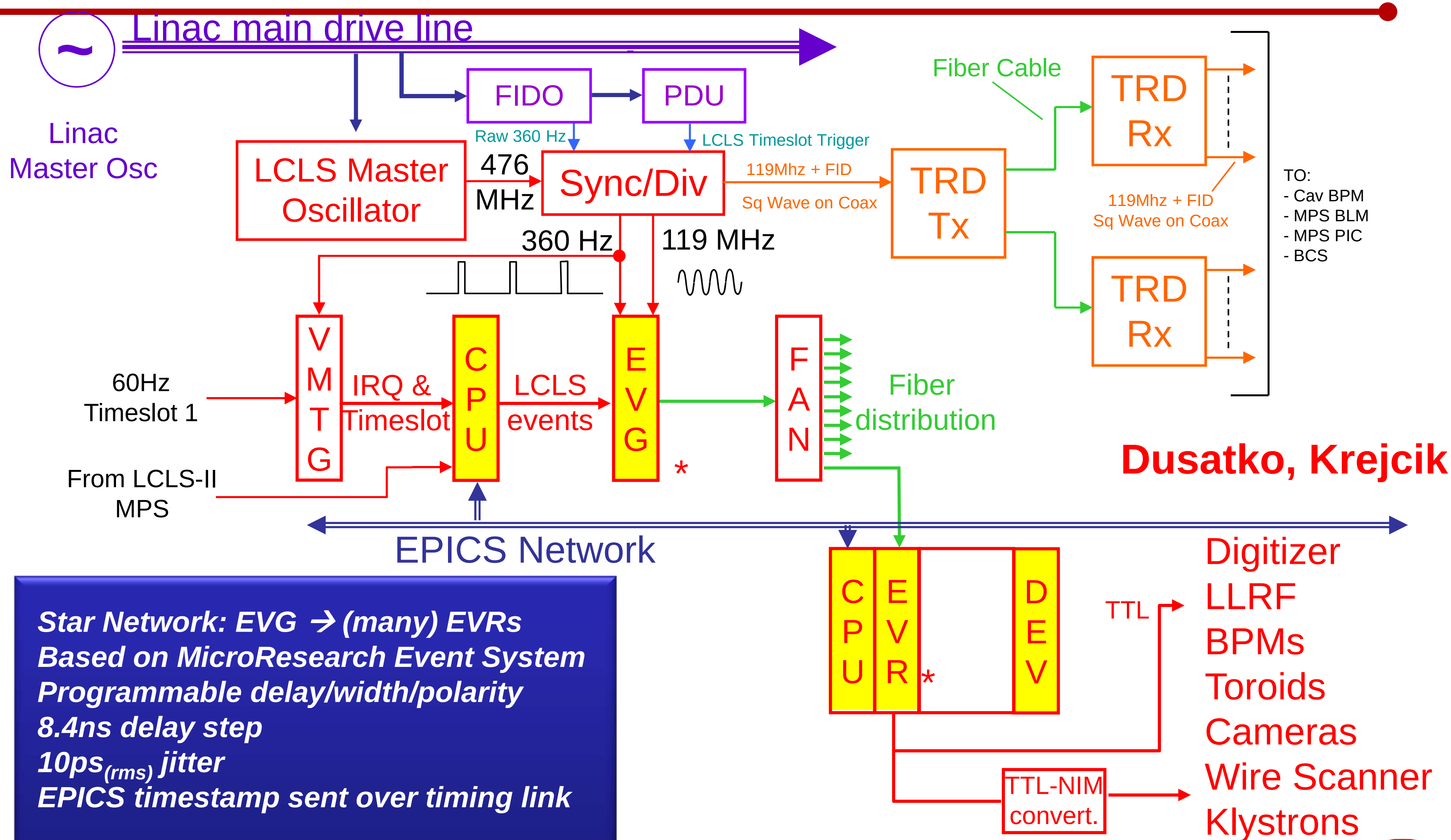
LCLS Timing Event System

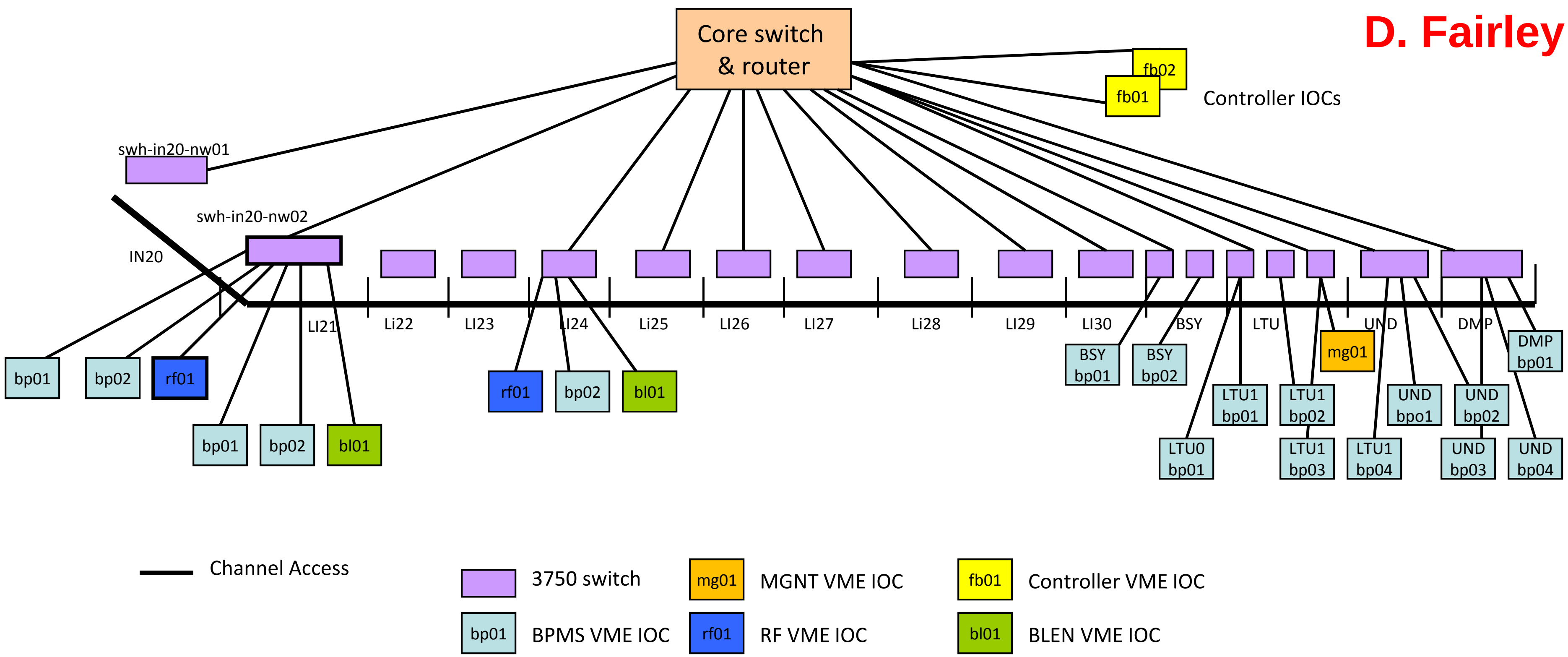


Star Network: EVG → (many) EVRs
Based on MicroResearch Event System
Programmable delay/width/polarity
8.4ns delay step
$10ps_{(rms)}$ jitter
EPICS timestamp sent over timing link

LCLS 120 Hz Feedback System

Dedicated network uplinks and connections to 2nd NIC on ~150 IOCs

D. Fairley



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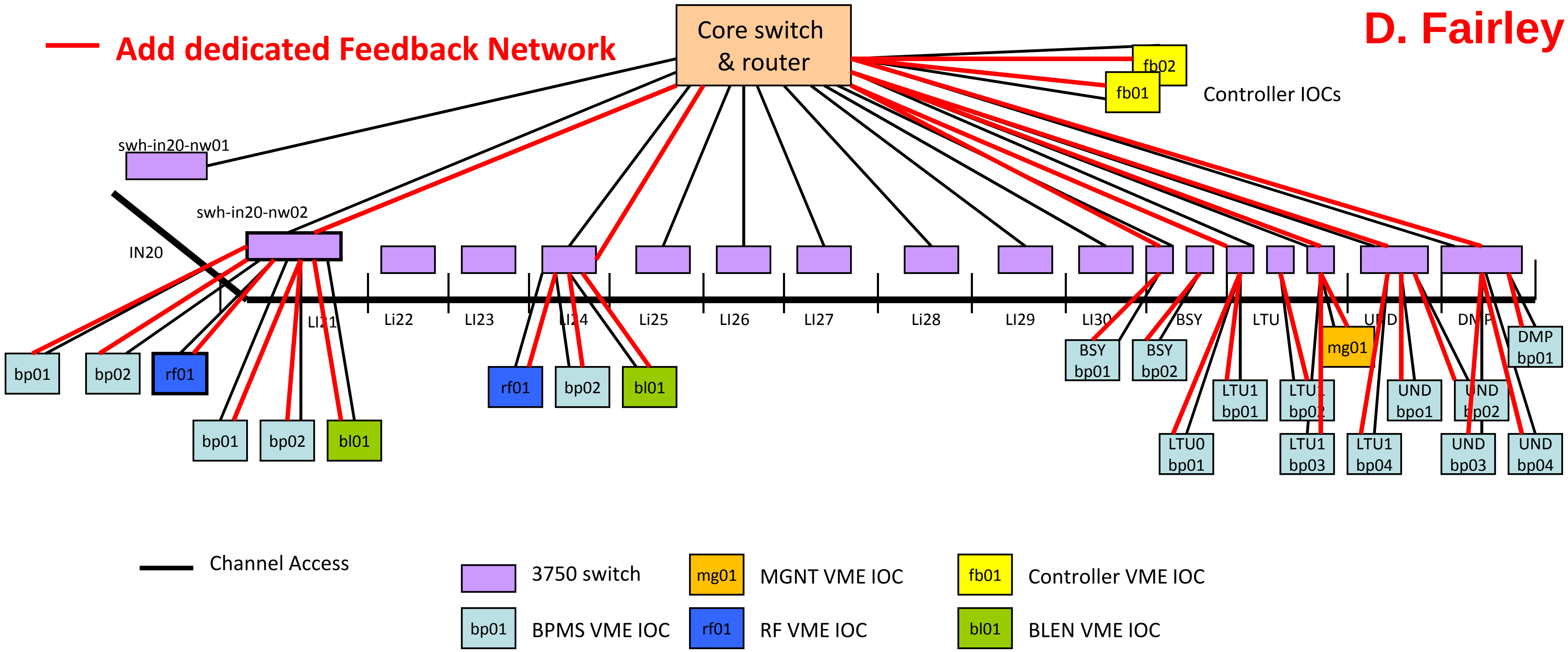
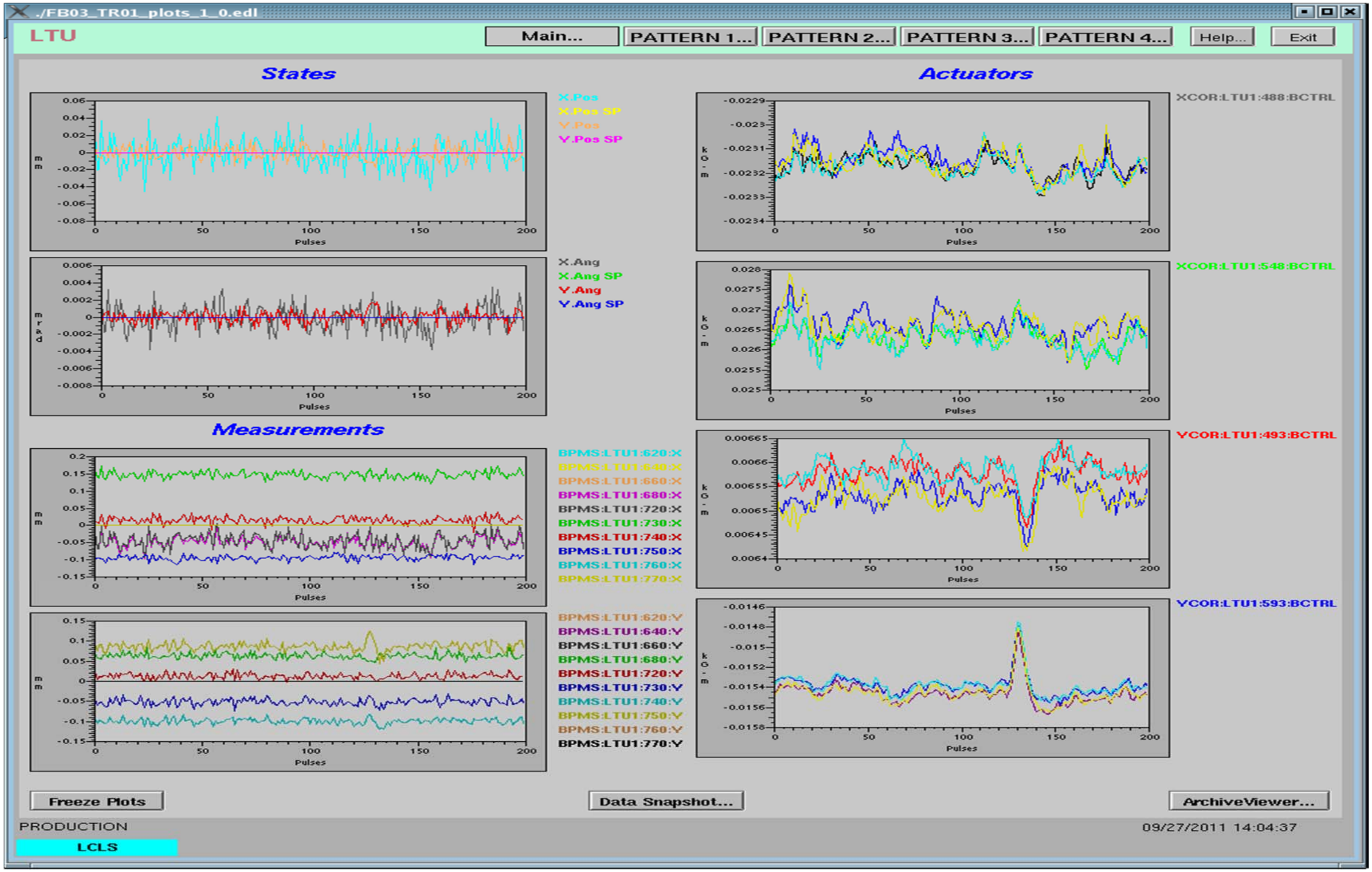
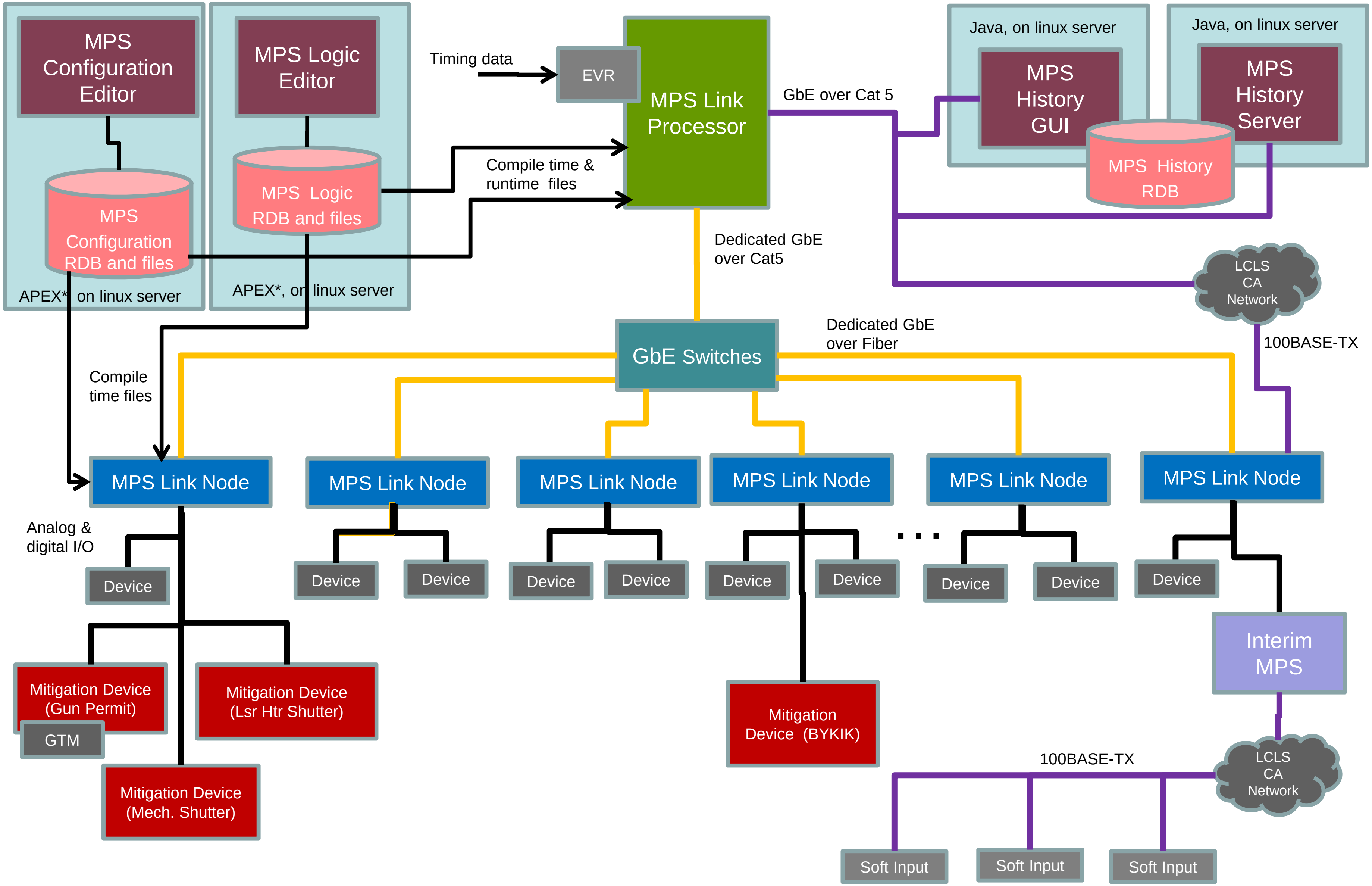


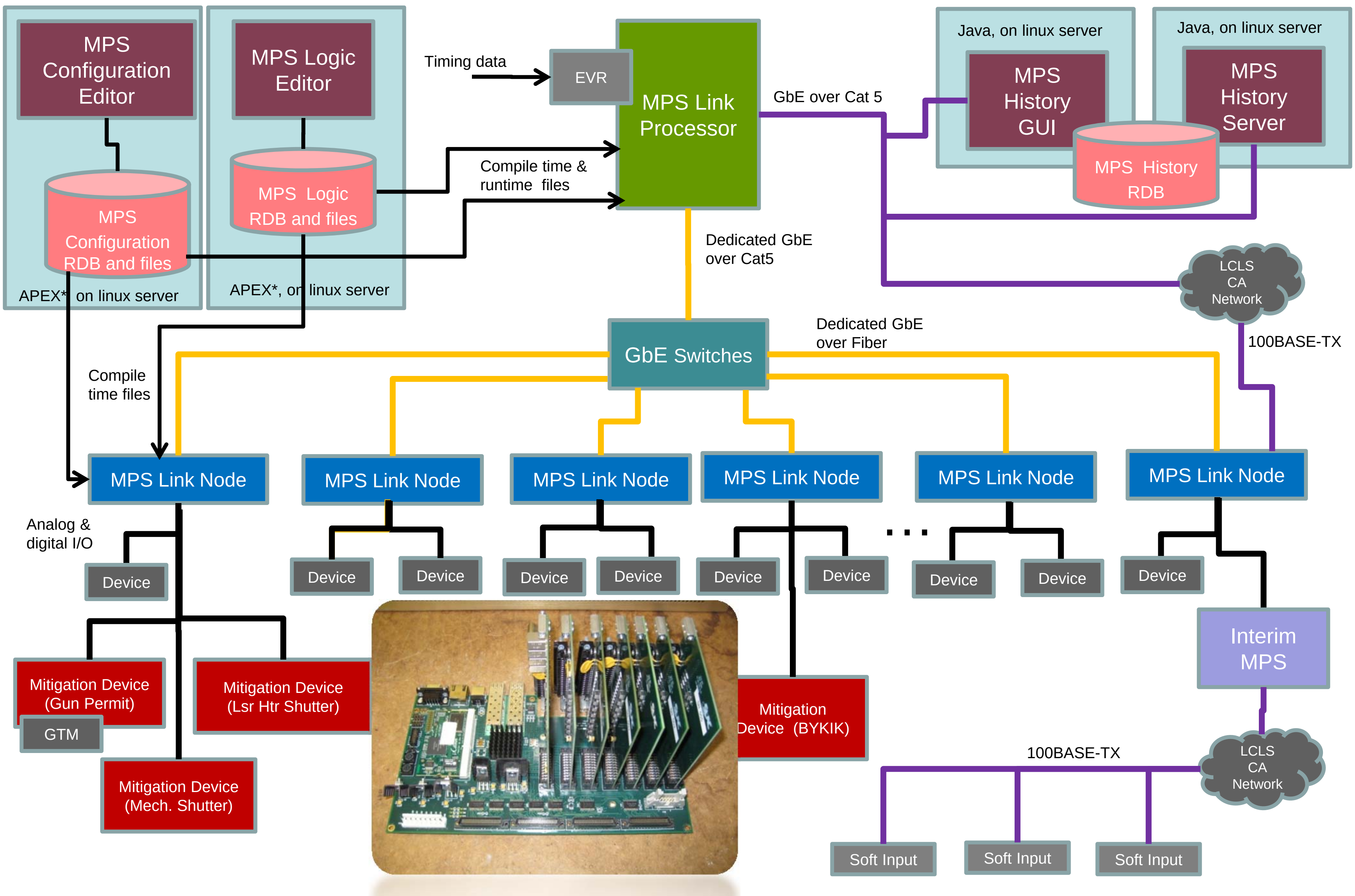
Runtime Feedback Display



LCLS Machine Protection Architecture



LCLS Machine Protection Architecture

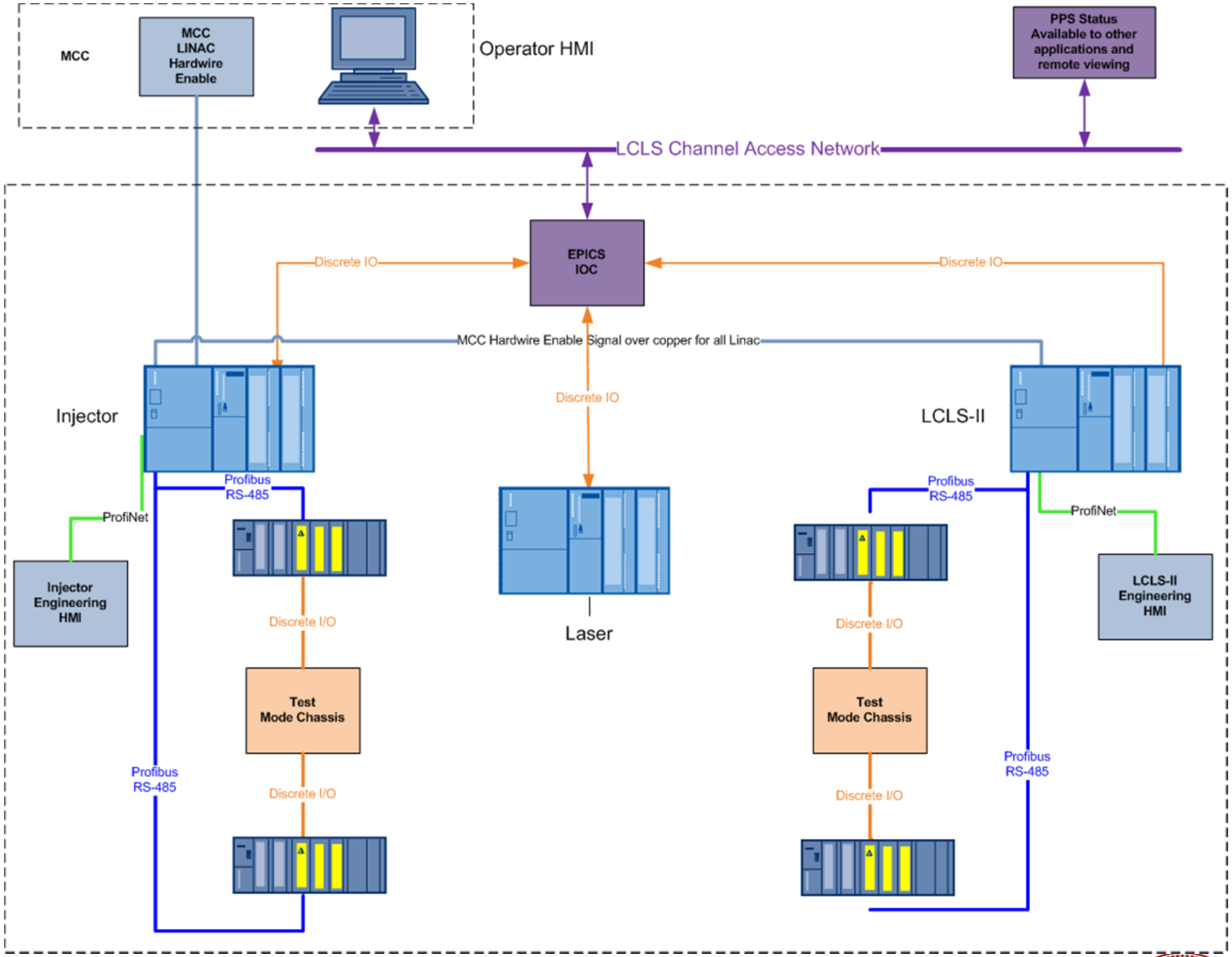


Personnel Protection System (PPS)

- Two redundant safety PLC (PILZ) independently programmed and validated

- Supervisor: Allen-Bradley

- EPICS interface IEC61508, ISO9001



Centralized RDB for Configuration Control

- LCLS Infrastructure includes a multi-function database of LCLS devices and related data
  - It is derived from the machine design model
  - includes beamline components, device information, polynomials, cabling data
  - laser device parameters
  - Field installed modules inventory
  - Links to QA documents and drawings
  - web interface for IRMIS and AIDA

RDB Applications

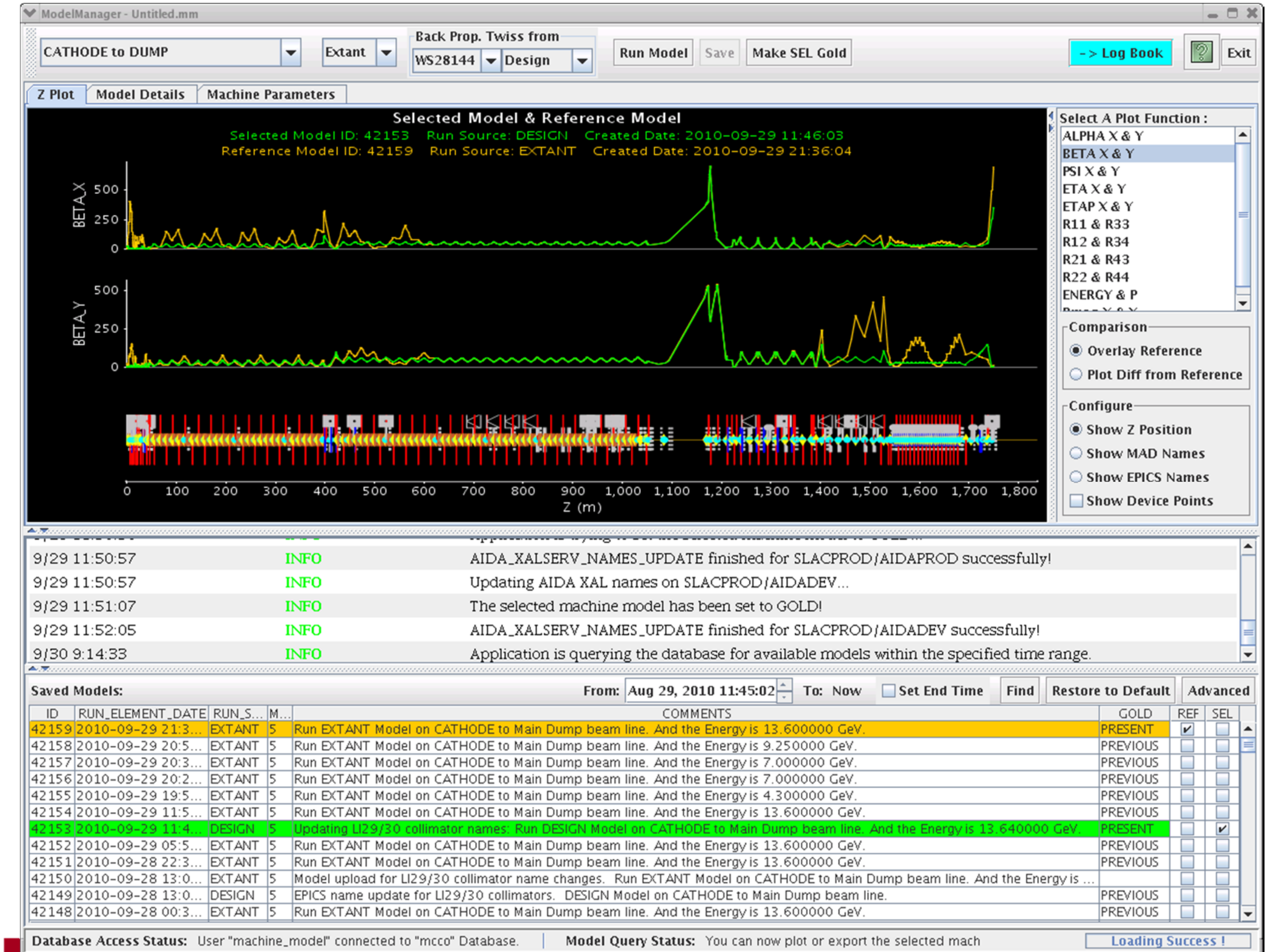
- Feedback Configuration parameters
- Save/Restore application
- Java and MATLAB physics applications parameters
- MPS faults history
- E-Log App
- CATER for Software Requests

High Level Application Software

Two-tiered approach

- Java-based utility applications
  - XAL machine modeling and tuning
- MATLAB / EPICS/AIDA infrastructure
  - Enabling physicists and operations staff to rapidly prototype required applications
  - Soft IOC framework for physicists
    - User-configurable PV records for physics data

Controls Model Based Apps– Model Manager



P. Chu

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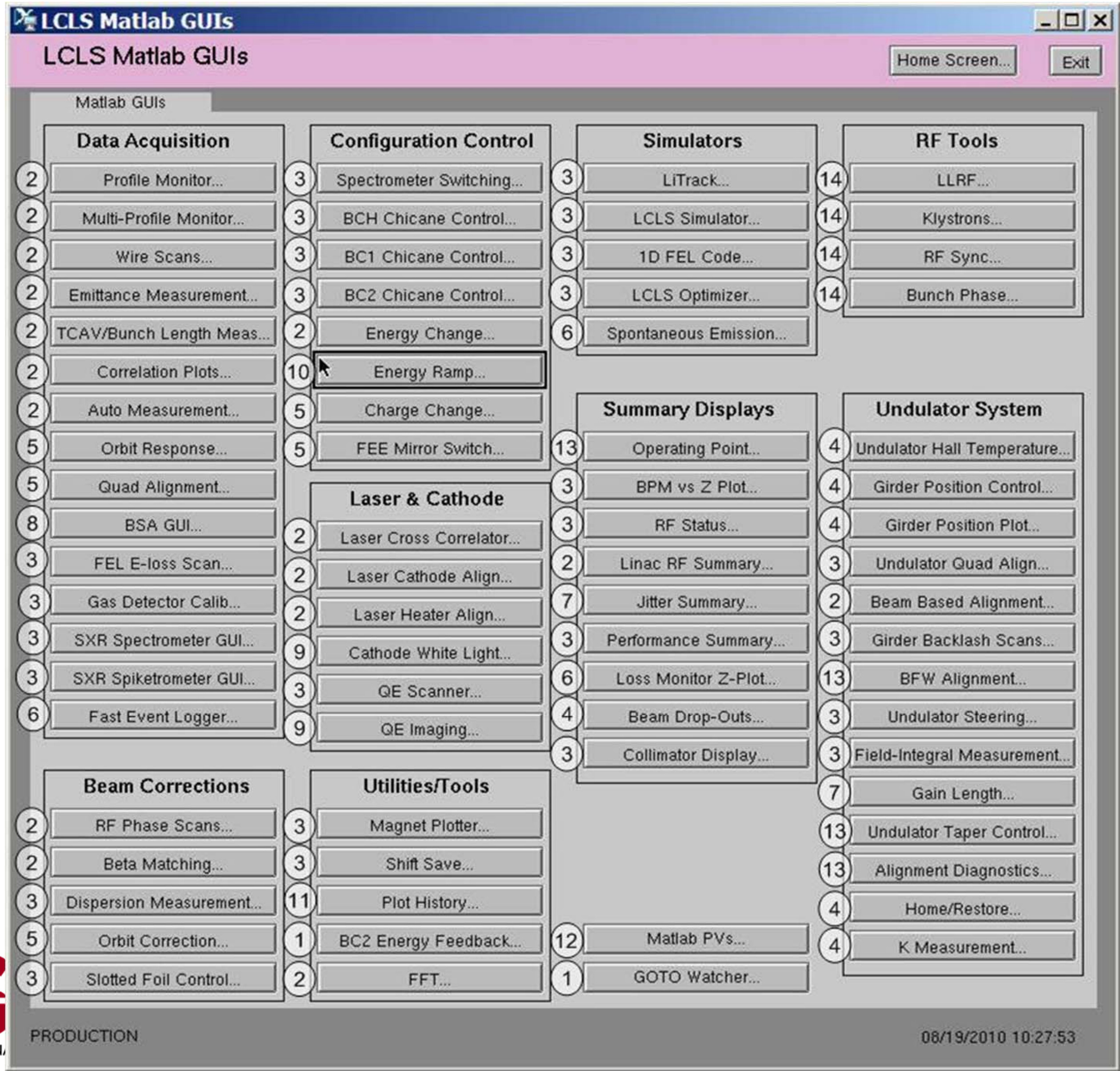
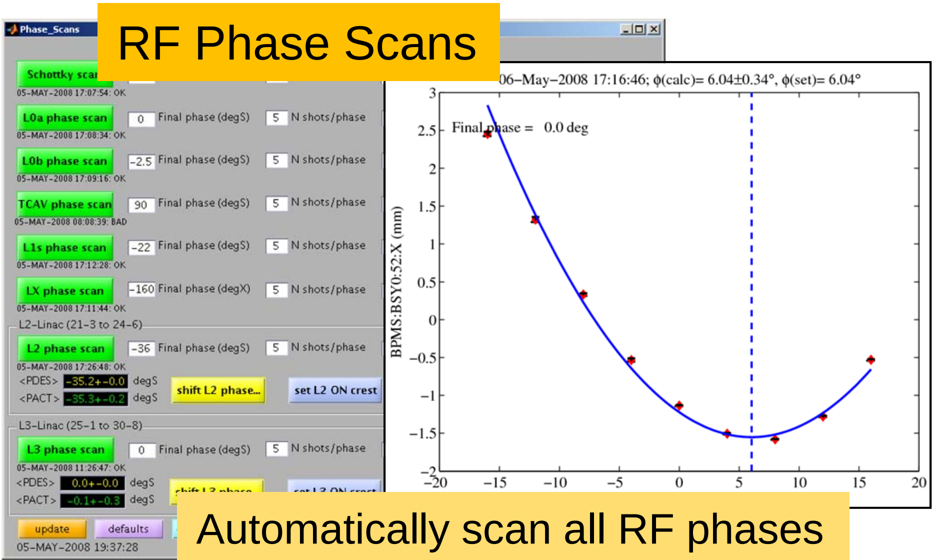
MATLAB High Level Physics Apps …



1. Joe Frisch
2. Henrik Loos
3. Paul Emma
4. Jim Welch
5. Jeff Rzepiela
6. Alan Fisher
7. Daniel Ratner
8. Jim Turner
9. Axel Brachmann
10. Nate Lipkowitz
11. William Colocho
12. Mike Zelazny
13. Heinz D. Nuhn
14. Pacak Vojtech

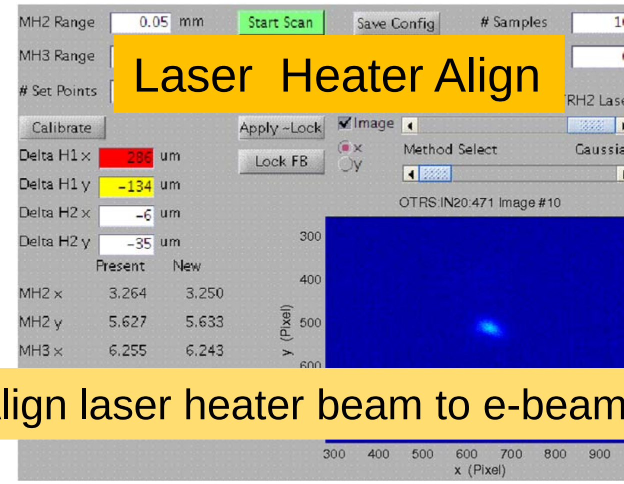
LCLS-I Automation Software

RF Phase Scans



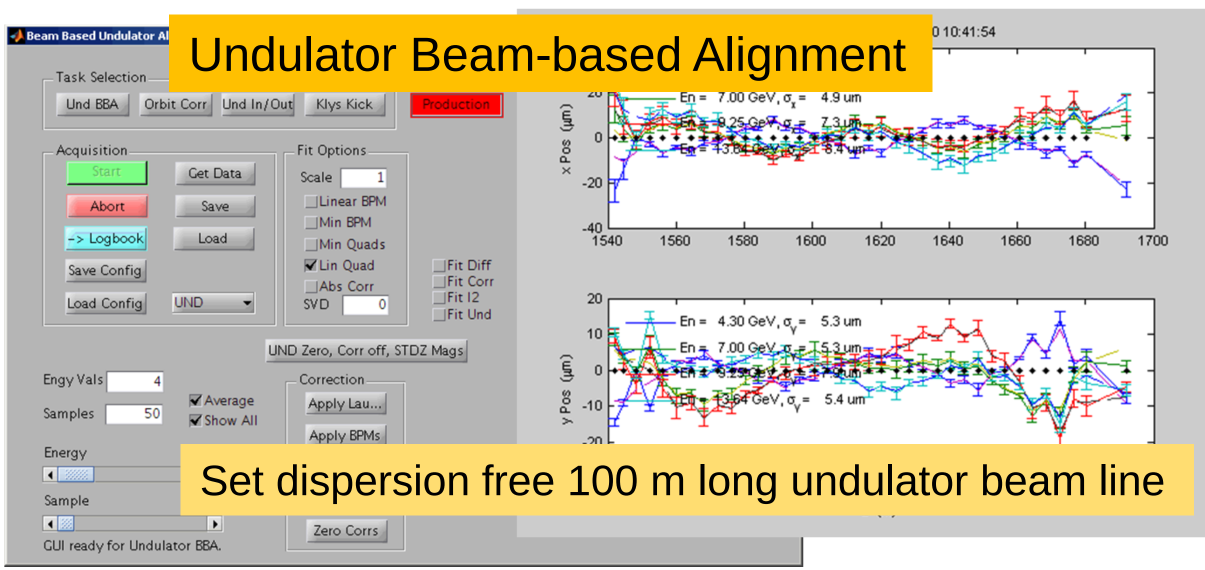
Automatically scan all RF phases

Laser Heater Align



Align laser heater beam to e-beam

Undulator Beam-based Alignment



Set dispersion free 100 m long undulator beam line

H. Loos

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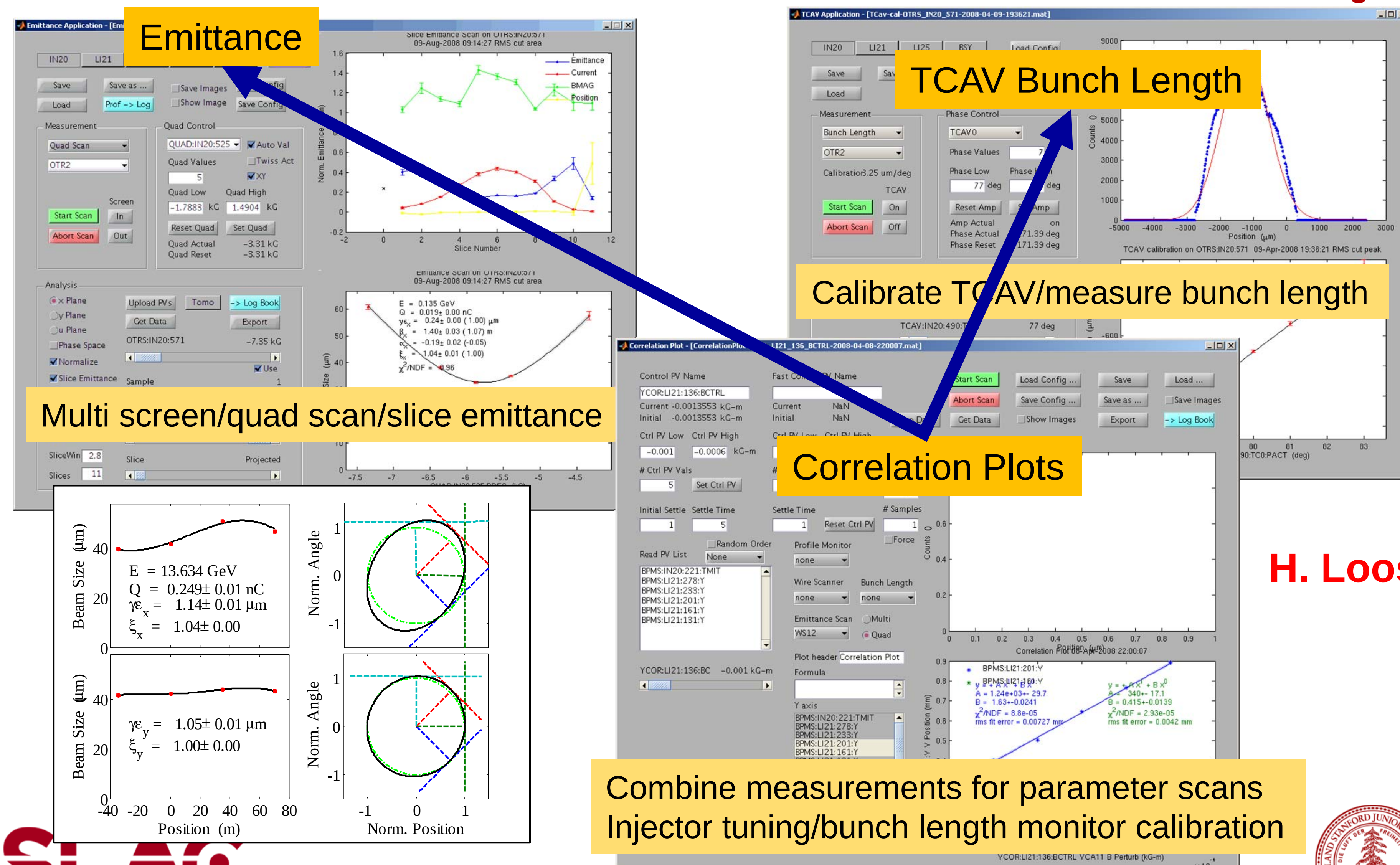
LCLS-I Automation Software



H. Loos

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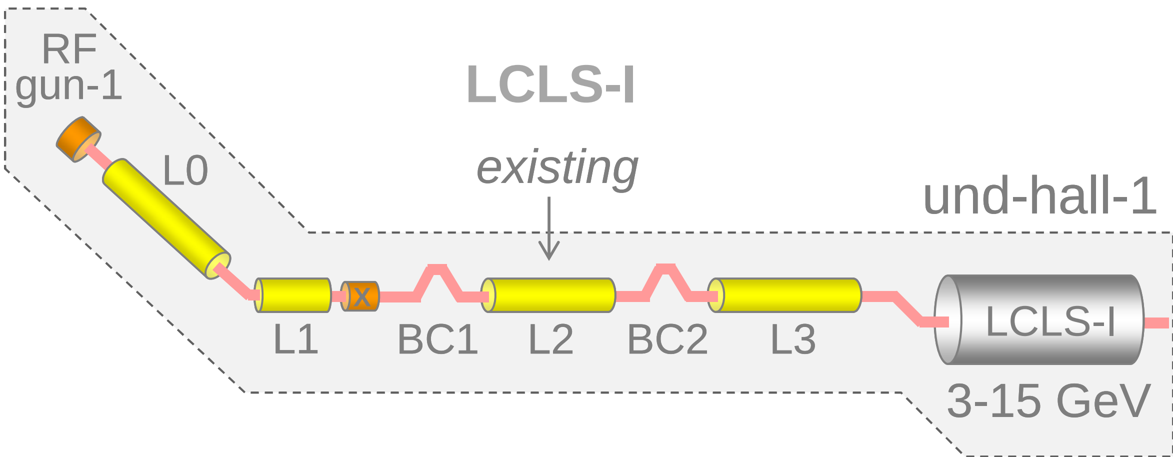
- Only 28% of users have received beam time
- Key Desired Capabilities Driving LCLS-II
  - More capacity & capability
  - One to four stations operating simultaneously
  - two injectors offering independent pulses
  - Extension to full intensity hard x-rays
  - study of thick 3D materials with increased x-ray penetration and spatial resolution
  - Extended soft x-ray spectral range

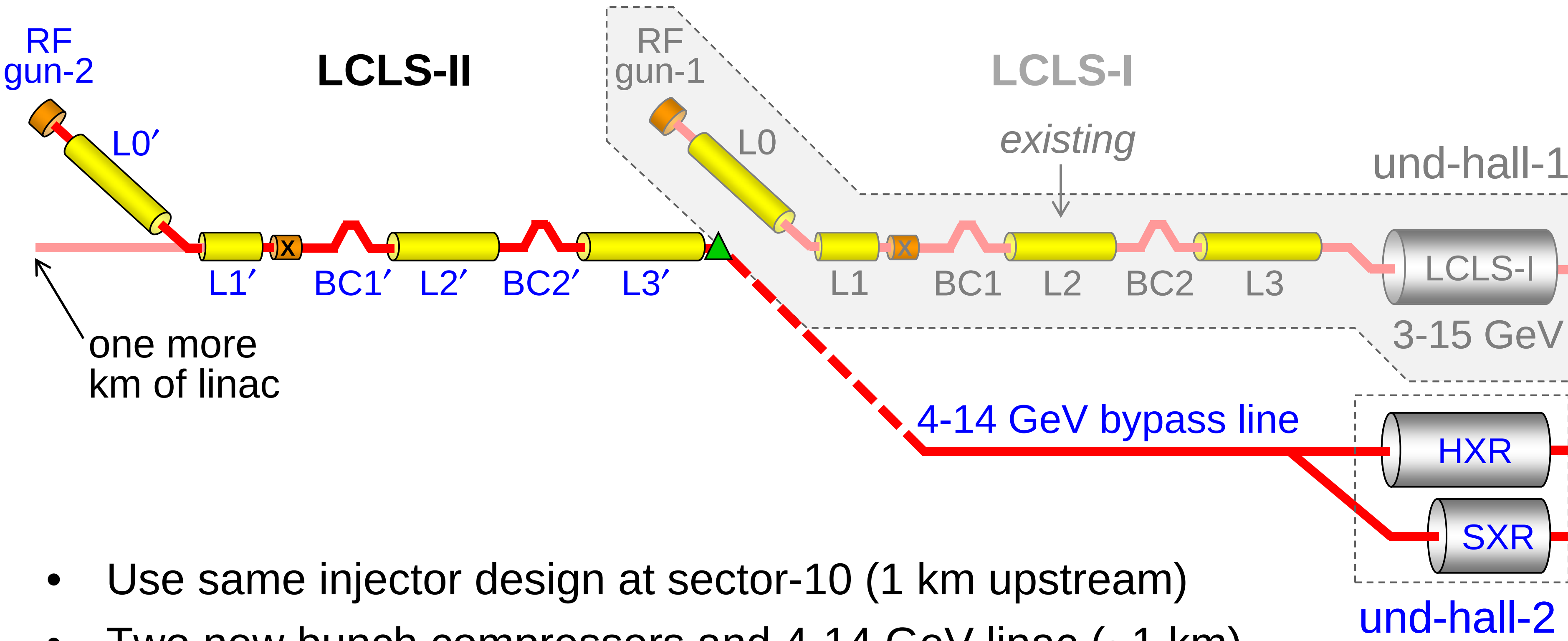
J. Stohr

LCLS-II Machine Layout



- Use same injector design at sector-10 (1 km upstream)
- Two new bunch compressors and 4-14 GeV linac (~1 km)
- 1200-m long bypass goes around LCLS-I
- Two new undulators (HXR & SXR) in new tunnel
- Baseline is 60 Hz in each undulator (multi-bunch later)

LCLS-II Machine Layout



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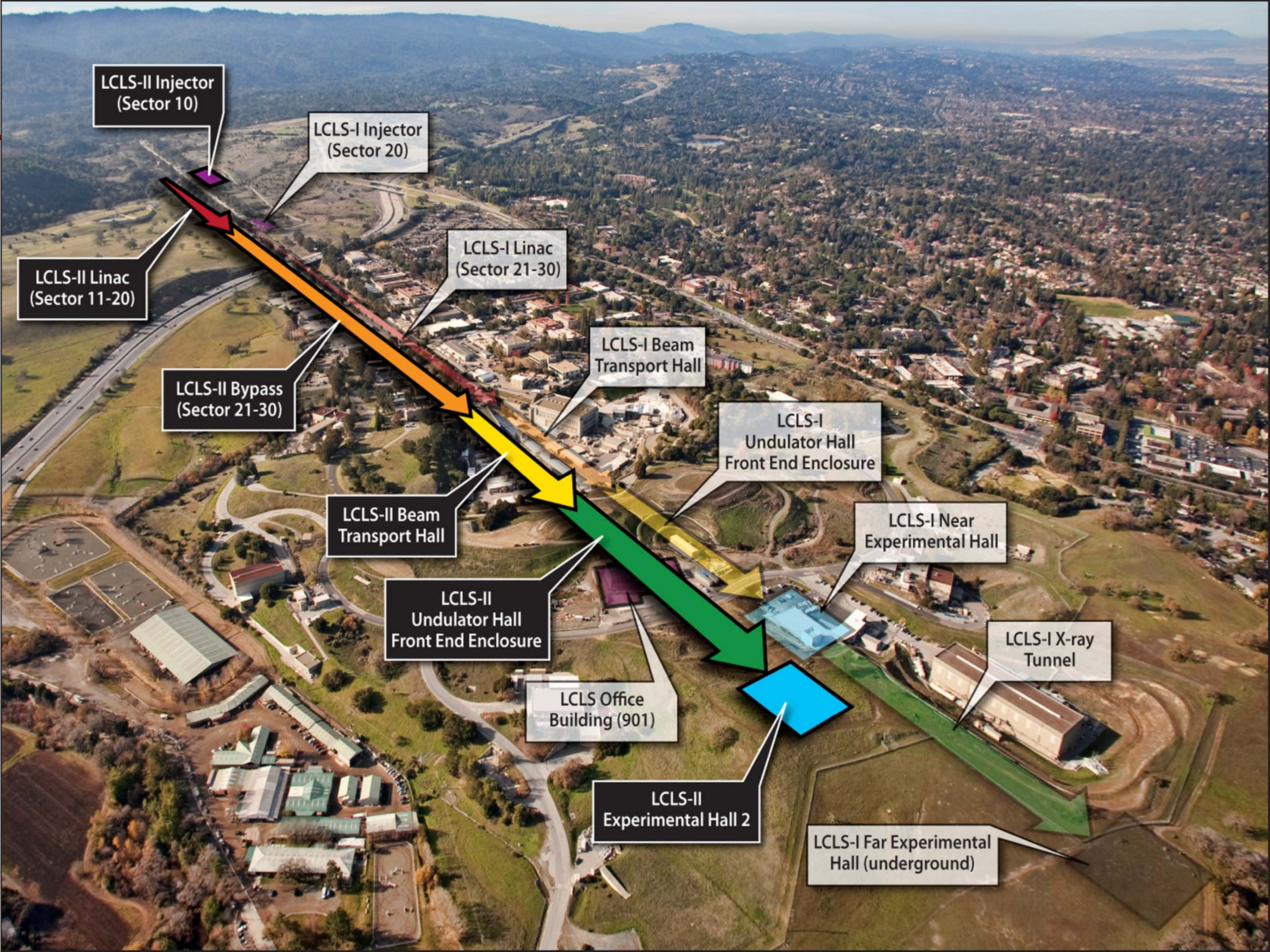


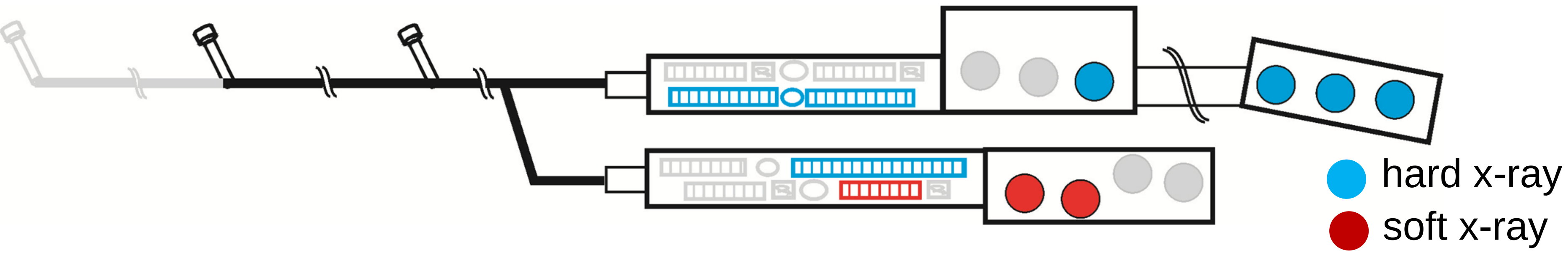
LCLS-II Injector (Sector 10)
LCLS-I Injector (Sector 20)
LCLS-II Linac (Sector 11-20)
LCLS-I Linac (Sector 21-30)
LCLS-II Bypass (Sector 21-30)
LCLS-I Beam Transport Hall
LCLS-I Undulator Hall Front End Enclosure
LCLS-II Beam Transport Hall
LCLS-I Near Experimental Hall
LCLS-II Undulator Hall Front End Enclosure
LCLS-I X-ray Tunnel
LCLS Office Building (901)
LCLS-II Experimental Hall 2
LCLS-I Far Experimental Hall (underground)

LCLS-II is part of a long term strategy

- 2 injectors, 2 linac sections (14 GeV each)
- 1 hard x-ray undulator 5-10keV in tunnel 1
- 1 hard x-ray SASE undulator in tunnel 2; (variable gap)
- 1 soft x-ray SASE undulator in tunnel 2; (variable gap)
- 6 experimental stations, up to 4 operating simultaneously
- Room for 4 more experimental stations

LCLS-II components in color, LCLS 2025 in grey

J. Stohr



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Advancing Controls to Meet Future Needs

- Migrating from CAMAC to new platforms
  - m-TCA platform research currently underway
  - Low Level RF field test of new system in 6 months
  - BPM m-TCA field tests April 2012
- Large-scale data archiving management
  - Scale to 1-2 millions PV's
  - Fast data retrieval
    - Days worth of 1Hz data for a PV in less than 500ms
- More automation of routine control room tasks

Conclusion

- LCLS has been an unqualified success exceeding performance goals
- Major challenge has been managing hybrid legacy-EPICS controls system
- LCLS-II and beyond will provide rich opportunities for advancing the state of controls and instrumentation
- Collaboration with Physics and Operations groups has been essential for success.