SLAC Overview and Future of Accelerator Science at SLAC

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Outline

- SLAC Overview: An Evolving Laboratory
- Overview of Particle and Particle Astrophysics Program
  - Operating program
  - Vision Forward Post-BaBar
- HEP Accelerator Operations Post B-factory
- Overview of Accelerator Research at SLAC

SLAC: The Lab is Changing

- SLAC's research vision is evolving dramatically.
  - The balance and content of the scientific foci is changing in substantial ways
- Photon science is rapidly expanding
  - In 2009, the major accelerator-based facilities will both be primarily serving photon science
- Particle Physics and Particle Astrophysics
  - Will no longer have forefront accelerator based HEP program on site.
  - Will be serving user community at accelerator facilities that will be off site
    - e.g. ILC; LHC
  - A vibrant program of accelerator research will continue
  - Non-accelerator efforts will grow


Damping
Rings
LCLS
Injector
Main Linac
PEP-II
End
Station B
SABER
NLCTA
End
Station A
SPEAR3
Guest
House
LCLS
LCLS
Near Hall
LCLS
Far Hall
CEH
BABAR

Overview of Particle Physics and Particle Astrophysics Program

B-Factory Physics Program

- Highly constrained and redundant set of precision tests of weak interactions in the Standard Model
  - legacy of fundamental constraints on future New Physics discoveries
- Searches for physics beyond the Standard Model
  - Sensitivity to New Physics at LHC mass scales
- B-factory program operates until end of FY2008
  - Final upgrades to machine and detector during FY06 shutdown
- Ultimate goal: Deliver to BaBar: ~1ab-1 end of FY2008
- Laboratory committed to delivering luminosity

Planning for FY09 Transition

- In FY09 the B-factory will stop operations; LCLS will start operations
  - The challenge we face between now and 2009 is the balance of the B-factory priorities with LCLS
    - A focus of the B-factory operations review last spring
  - We recognize this challenge and it is being actively and aggressively managed
- Transition planning well underway
  - Led by PSD and Keith Hodgson

Looking Forward: The Mission for SLAC PPA Post BaBar

- Our scientific mission looking forward has three major elements:
  - Accelerator based research at the energy frontier
    - ILC, LCD, ATLAS, Accelerator Research
  - Investigations of Dark Matter and Dark Energy (non-accelerator)
    - GLAST, LSST, JDEM
  - Investigations in neutrino physics to understand (a) what are the masses of the neutrinos and (b) are neutrinos their own anti-particles?
    - EXO

Program Timelines: Exploiting the present and preparing for the future

- Science now or soon
  - BaBar (ops to 2008, science to 2012?)
  - GLAST (2007 – 2012/17)
  - LHC: ATLAS & LARP
  - Proof of principle experiments in accelerator research
- R&D for near term science (2012 and beyond)
  - ILC/LCD
  - LSST
  - EXO
  - SNAP
- R&D for farther future
  - High Gradient Program
  - Accelerator Research

Focus of this EPAC

The Energy Frontier: ILC

- The highest priority for the international field of particle physics is the full, direct exploration of the TeV energy scale.
  - with high probability new physics will be there
- SLAC is committed to the ILC
  - SLAC staff are broadly involved in all elements aspects of the ILC effort
  - We are lagging behind Europe in detector development due to lack of resources
    - Some hope situation will improve in FY07

The Energy Frontier: LHC

- SLAC Participation in LHC
  - Participation in LHC Accelerator Research Program (LARP)
    - Designing collimators for LHC/LHC Upgrades
    - Will also support beam commissioning
  - SLAC group accepted into ATLAS
    - Participation off to good start
      - Attracting excellent postdocs and students
  - Won competition to host Tier 2 at SLAC
    - Supported by all west coast ATLAS institutions
    - Partnering with UCSC and LBNL will have very strong west coast hub for ATLAS community

The Energy Frontier: Accelerator Research

- Accelerator Research for Future Machines
  - High Gradient Studies for CLIC type machine
  - Development of L-band power sources for ILC
- Proof of Principle Studies of New Acceleration Mechanisms:
  - Plasma Acceleration Experiment
    - FFTB→SABER
  - Laser Acceleration
    - NLCTA

Particle Astrophysics and Cosmology and Neutrinos

- Gamma Ray Large Area Space Telescope (GLAST) continues to march towards launch
  - Growing understanding of GLAST's role in dark matter campaign
    - Baltz, Battaglia and Peskin; **hep-ph/0602187**
- The Dark Universe, unknown to us until just recently, is ours to explore
  - Tremendous scientific opportunities with LSST and JDEM/SNAP
    - SLAC is the leader of the DOE-based effort in the LSST R&D.
    - LBNL is the clear and highly competent leader of SNAP concept and we have an important, well defined support role
- Determining fundamental nature of neutrino with search for $\beta\beta0\nu$ decay in $^{136}Xe \rightarrow {}^{136}Ba^{++}\ e^{-}\ e^{-}$
  - EXO will go underground at WIPP in April

HEP Accelerator Operations Post B-factory

Program Assumptions for 2009

- LCLS Operations
  - Operations of 1/3 of linac (120 Hz operations) plus LCLS injector, undulator and controls systems
  - Maintenance of full linac
- LCLS Construction
  - Includes completion of project and planned start on expansion program in FY09 (2nd undulator)
- PSD Program
  - SSRL – SPEAR3 operations and scientific programs
  - LCLS experimental science program
- PPA Program
  - Particle and particle astrophysics scientific programs
  - ILC
    - Significant growth in ILC R&D assumed
  - Operations of SABER and NLCTA

Future Business Model

- BES Primary Stewardship
  - BES Supports Linac Ops (1/3 of Linac)
  - BES Supports Linac Maintenance (full Linac)
  - BES covers org costs and direct program support costs for Linac related accelerator operations: includes all major technical infrastructure at the laboratory essential to accelerator operations
    - Klystron, CPE, CEF, Scientific Computing Infrastructure
  - HEP accelerator based programs (SABER, NLCTA, ILC) leverage off BES base
    - Significant uncertainty in HEP use of core technical infrastructure (i.e. ILC)
    - Success of LCLS cannot depend on future of HEP funding to these departments
- HEP and BES share site-wide indirect costs
- This model is proposed so that operations support for LCLS will not be dependent on future HEP programs (e.g. ILC)

Operations in 2009

- SLAC has defined its operating scenario for FY09 and beyond
  - Detailed review by BES has endorsed the proposed model and funding level
- Budgeting and accounting structures in place to manage the transition
  - Will be able to respond to uncertain budget scenarios
- The business model and funding level provides and opportunity for continued HEP use of SLAC Linac for forefront accelerator R&D for modest investment

Overview of Accelerator Research at SLAC

Accelerator Research and Technology at SLAC

- Long tradition of accelerator R&D working with users to develop new technologies and machine concepts needed to accomplish research goals
- Cross-cutting activity that spans entire lab
- Core competency of lab that benefits current and future operations
- Need organization and leadership that allows lab to capture cross-cutting opportunities in accelerator R&D that are central to future success of lab and other Office of Science programs
  - Organization must be flexible and responsive to changing laboratory

Accelerator Physics at SLAC: Mission

- Operations of facilities & near term improvements
  - PEP-II
  - SPEAR3
- Design, construction and commissioning of the next generation of machines & their upgrades
  - LCLS
  - ILC
  - LHC (LARP)
  - Future light sources
- Development of new technologies
  - Injector Test Facility
  - Photocathode Gun Development
  - High Gradient Acceleration Technologies
- R&D in new acceleration mechanisms
  - To make future generations of machines feasible and affordable
- Education of next generation of accelerator scientists and engineers

Organization

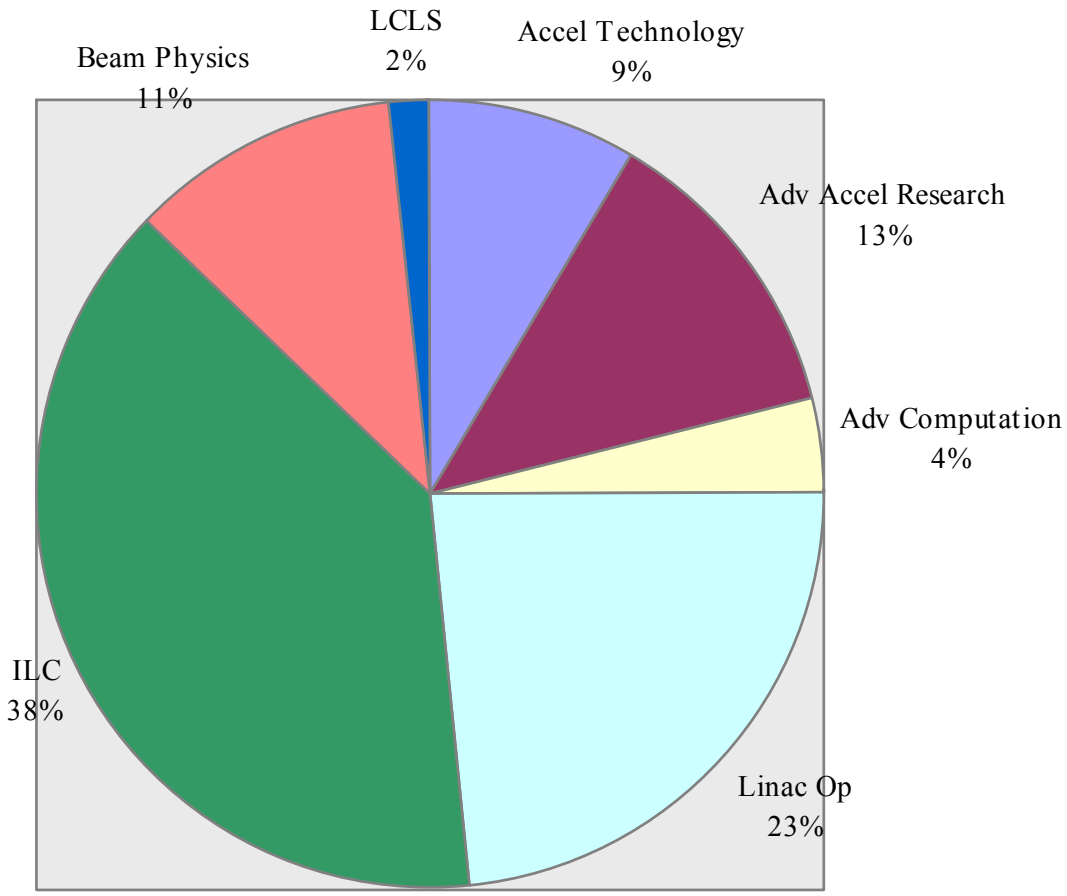
- Particle and Particle Astrophysics
  - ILC Division
  - Accelerator Systems Division
  - Accelerator Research Division
    - Beam Physics Department
    - Accelerator Technology Research Department
    - Advanced Computing Department
    - Advanced Accelerator Research Department
- Photon Science
  - SSRL Accelerator Systems Department
- LCLS
  - Accelerator Physics Group
- Operations
  - Klystron
  - CPE
  - SMS

Balance of effort between basic research and helping to solve problems of the ongoing and future programs (eg ILC, LCLS, B-factory)

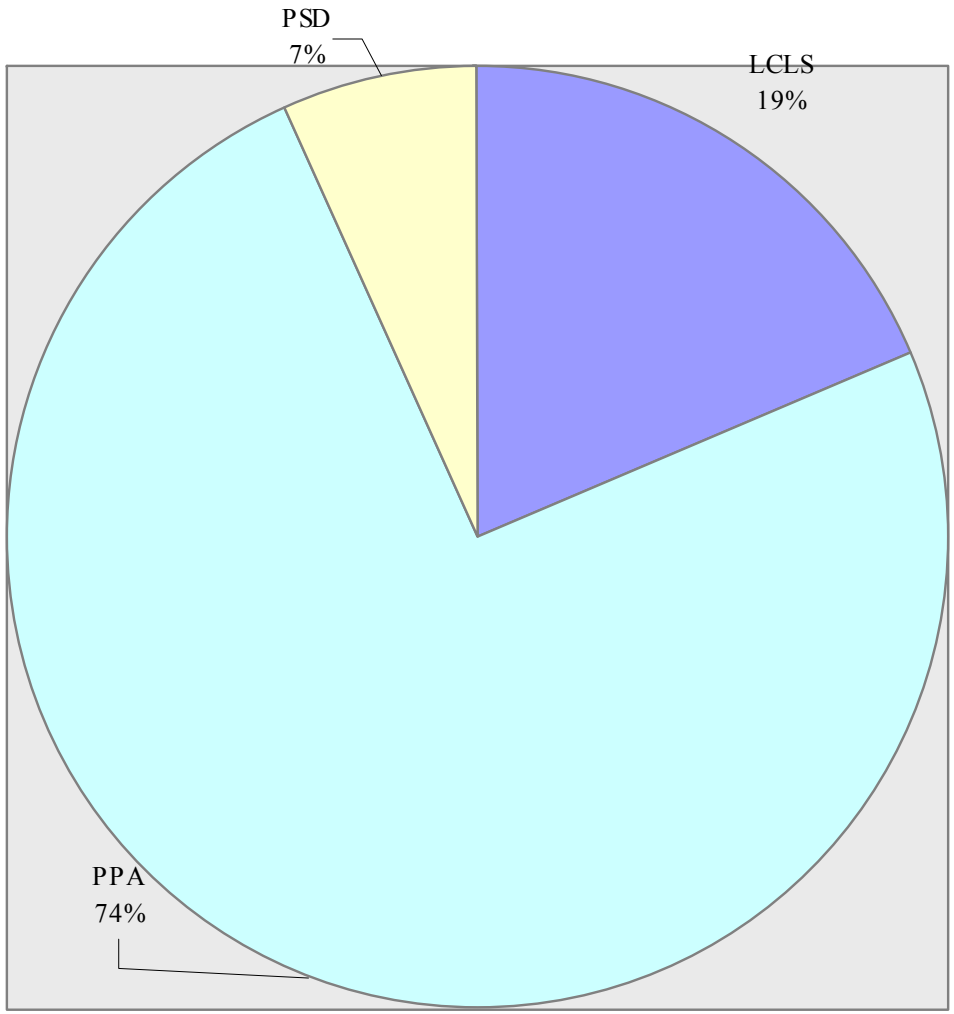
Technical support coupled to other efforts

Human Resources--PPA

~100 Accelerator Scientists including students and postdocs



Human Resources—Site Wide



Accelerator Research Activities

Advanced Accelerator Research Department (AARD)--PPA

- experimental research in high gradient acceleration
- microstructure design & fabrication
- dielectric wakefield acceleration
- beam-plasma physics
- laser driven dielectric structures
- high gradient plasma acceleration
- beam diagnostics for femtosecond and attosecond beams

Advanced Technology Research Department (ATR)--PPA

- high gradient structures and ultra high power RF sources and switching technology
- advanced accelerator concepts
- novel FEL and light source technologies
- superconducting materials research
- advanced electronics for instrumentation, control, timing

Advanced Computation Department (ACD)--PPA

- CSR, micro-bunching calculation
- design/modeling of low-emittance rf photo-cathode gun
- modeling code development
- design and analysis of EM structures (e.g., RF deflector)
- simulations of wakefields in undulator and impedances in vacuum chambers

Beam Physics Department (BPD)--PPA

- CSR and its effects
- accel optics theory, development and measurement
- FEL studies
- lattice modeling code development (LEGO, BBI, Zlib, MIA)
- impedance and wakefield studies
- beam dynamics and phase space manipulations
- new light source concepts
- compressor micro-bunching instability studies

Accelerator Research Activities

Accelerator Systems Division (ASD)--PPA

- ring and linac lattice modeling and development
- beam dynamics
- electron cloud instability studies
- I&C development
- new ring concepts

Controls and Power Electronics Department (CPE)--OPS

- solid-state klystron modulators
- high availability power supplies, pulsers and controls
- intelligent diagnostic systems
- future instrument standards for accelerators and detectors
- advanced beam instrumentation
- signal processing and feedback system development

International Linear Collider Division (ILC)-PPA

- high brightness injectors
- polarized electron and positron sources
- linac, damping ring and IP design
- impedance, wakefield and EMI studies
- energy spectrometer development
- advanced accelerator technology and instrumentation
- high power collimator development as part of LHC Accelerator Research Project (LARP)

Klystron Department (Kly)--OPS

- rf power source development
- power sources and test facility for rf structures (incl. LCLS)
- LLRF timing distribution/stabilization
- design support for beam diagnostics

Accelerator Research Activities

LCLS Laser Group --LCLS

- laser techniques for improved gun performance (shaping, UV conversion, etc.)
- laser, X-ray timing/synchronization
- bunch control for shorter X-ray pulses

LCLS Physics Group -LCLS

- FEL physics (SASE, seeding, etc.)
- ultra-short beam production
- timing synchronization
- photocathode guns and injector
- technologies for enhanced photon production
- multi-bunch ops and fast switching
- fast start-to-end simulations, controls integration

SSRL Accelerator Systems Department (SASD)--PSD

- ring and ID modeling, development
- new lattice development
- beam dynamics studies
- short bunch and timing modes
- top-off injection
- I&C development
- future improvements (e.g., ERL) and new ring light source concepts

Surface and Materials Science Department (SMS)--OPS

- R&D on photoemissive cathodes
- chamber finishes that suppress secondary electron emission
- causes of breakdown-generating electron emission from materials in high-electric fields

Operations Facilities

- LINAC:
  - 50 GeV e+ and e- 120 Hz at 2 x 10^{10}
  - Currently full linac operationed by HEP
  - 2009: Full linac maintained by BES; final 1/3 operated by BES,
- PEP-II:
  - 3.1 GeV e+ injection up to 30 Hz at 1 x 10^{10}
  - 9.0 GeV e- injection up to 30 Hz at 1 x 10^{10}
- SPEAR3 and injector:
  - 3 GeV e- injection storage ring light source
- LCLS:
  - 14.5 GeV e- up to 120 Hz at 4 x 10^{9}
  - Uses final 1/3 of linac
  - First 2/3 of linac maintained for future upgrade options

R&D Facilities

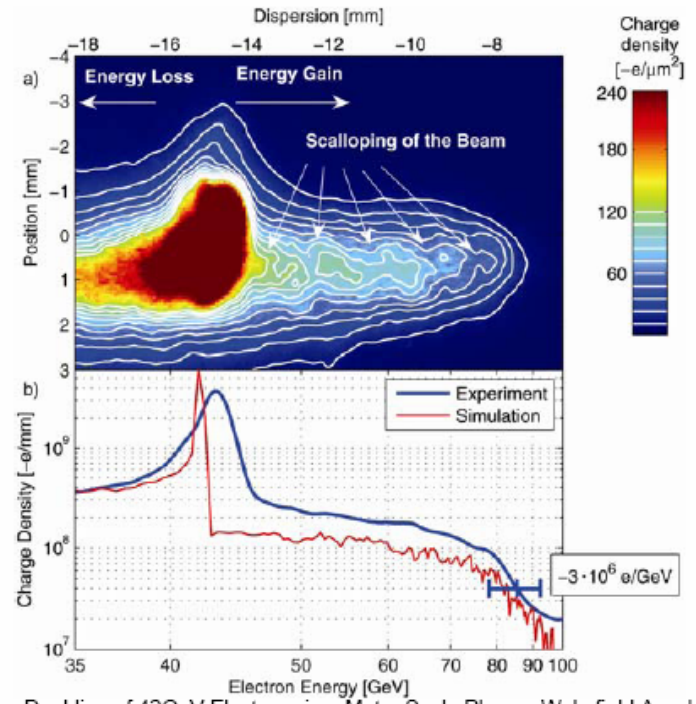
- NLCTA & ESB
  - 300 MeV e- accelerator & RF Test stations
  - Moving from NLC research tool to research facility for accelerator research
    - Evolution in management structure
- SABER
  - Relocation of FFTB
  - 28 GeV low emittance e- and e+ beams for accelerator research
  - Hope to start construction this year
  - Uses first 2/3 of linac maintained by BES (SABER ops funded by HEP)
- ESA
  - Excellent, large, instrumented crane covered space
    - Still used for some test beams
  - Future site for ILC RF R&D
- Accelerator Structure Test Area (ASTA)
  - Test facility for gun development and high gradient research
- Gun Test Facility (GTF at SSRL)
- Injector Test Facility (Proposed)

Current Issues Facing Accelerator Research

- Saber
  - Funding
  - Operations
- NLCTA
  - Management changes going forward
  - What is the research portfolio going forward?
- ITF
  - Proposal stage now
  - Essential for future of LCLS

SABER

- Spectacular results from final FFTB run
  - Demonstrated 42GeV of acceleration in 0.9m plasma
  - Highest energy electrons ever made at SLAC
- SABER (FFTB replacement) in development
  - In discussions with DOE about funding and timeline
  - DOE review 12/6 & 7



Energy Doubling of 42GeV Electrons in a Meter Scale Plasma Wakefield Accelerator [Submitted to Nature (2006)]

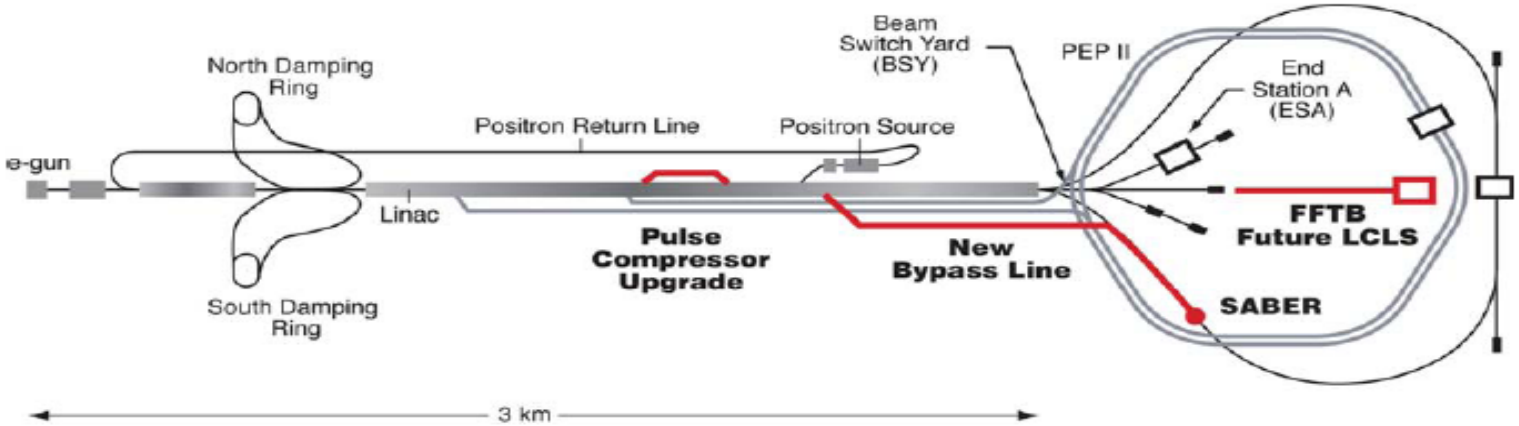


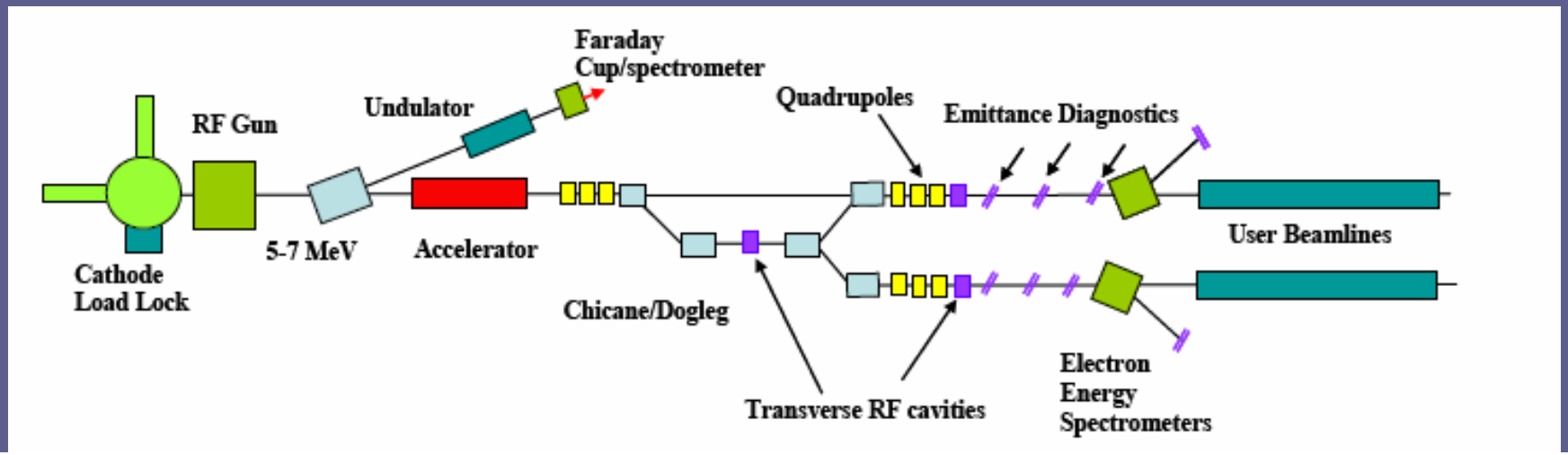
Figure 1. SABER at the SLAC accelerator facility.

NLCTA

- E163: Laser Acceleration at NLCTA
  - A series of experiments to demonstrate the physics and technical feasibility of laser acceleration
    - Facilities are nearing completion, and await a final Accelerator Readiness Review on December 18th
  - E163 facilities include:
    - A new single-pulse low-energy-spread electron source for the NLCTA
    - A 10 GW ultrafast laser system
    - A new shielded experimental enclosure which can be accessed while the NLCTA runs
- High Gradient Program at NLCTA and ASTA
  - NLCTA: 3 RF stations, one Injector, Radiation shielding
    - System suitable for testing novel rf accelerator structures and waveguide structures
- Will move to management by ASD more suitable for multi-user facility

Injector Test Facility

- "The electron gun is the critical enabling technology for advancing LINAC based light sources" BESAC 20-year facilities road map
- Test facility needed to push parameters of beam brightness
  - Leads to shorter wavelength radiation
  - New science opportunities
- White paper identifies opportunities and costs for development of ITF at SLAC
- Challenges to be addressed in rf photocathode gun development
  - Cathode development
  - Laser performance
  - Gun design
  - Post-acceleration beam conditioning
  - Simulation



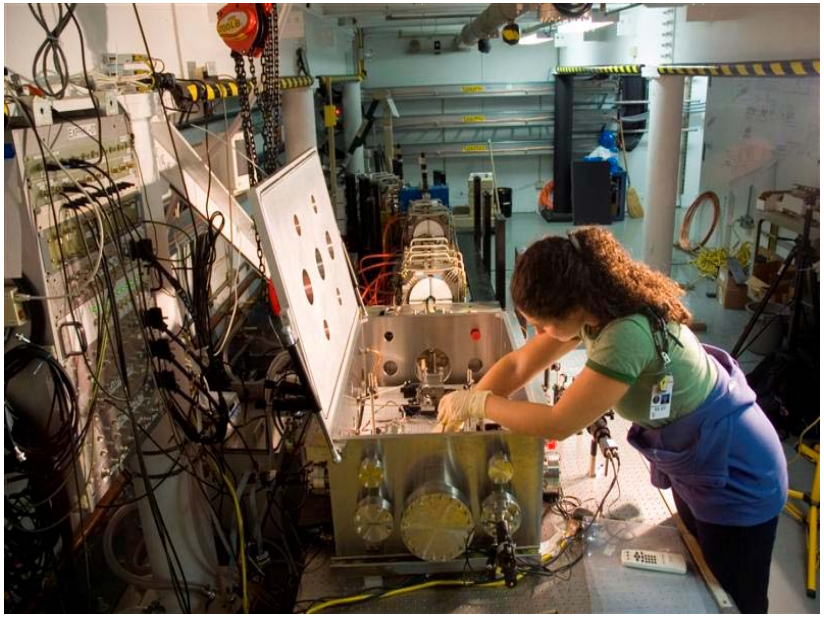
Summary

- SLAC in time of transition
  - Changes from past
  - Exciting opportunities for the future
- SLAC has defined its operating scenario for FY09 and beyond
  - Detailed review by BES has endorsed the proposed model and funding level
- Development of Accelerator Research Facilities for 2009 and beyond well underway
- SABER and important element of continued rich and diverse accelerator research program at the lab
  - Mission broadening to include more focus on future photon science opportunities

Back-up Slides

NLCTA

E163: Laser Acceleration at the NLCTA



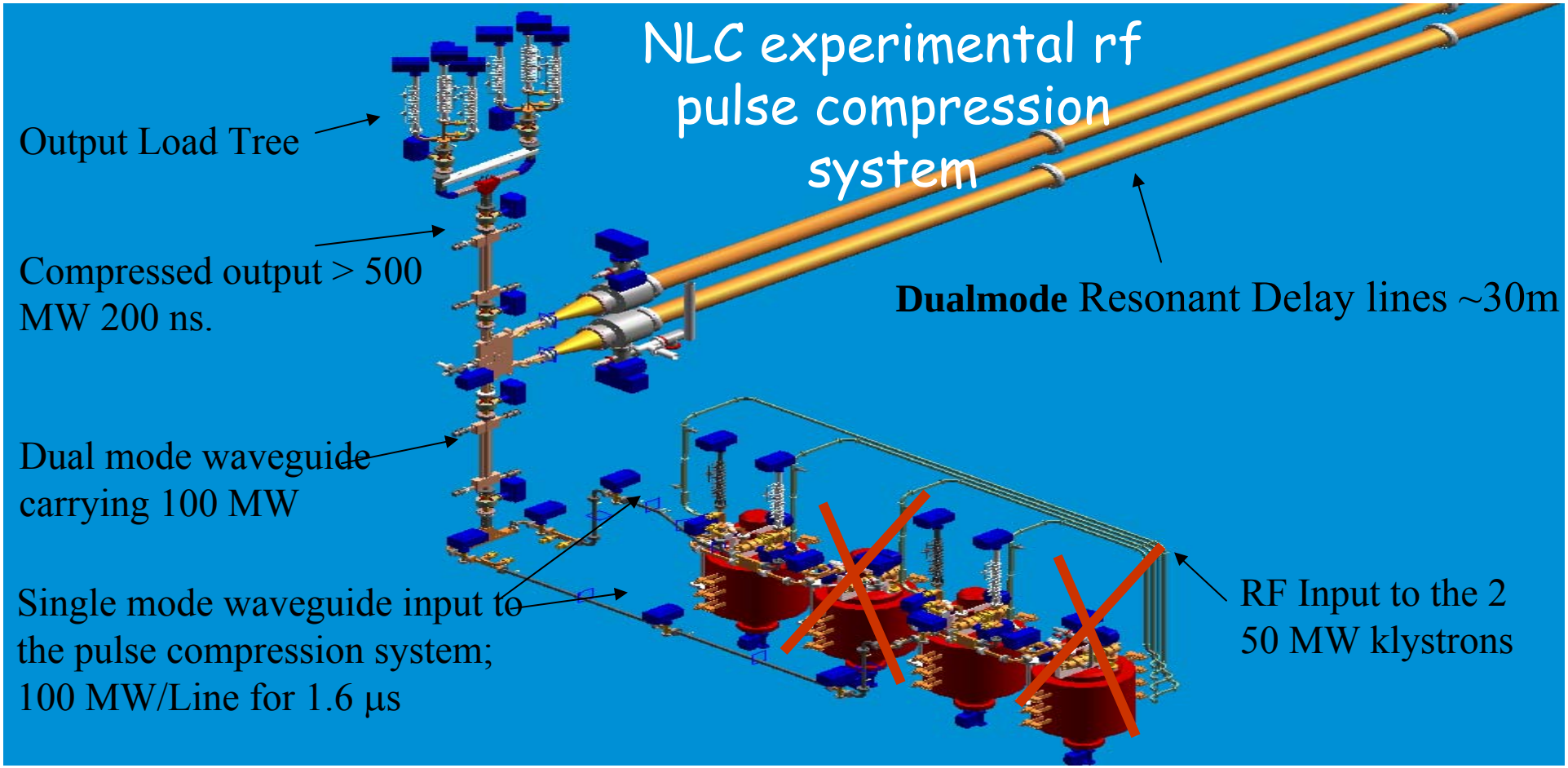
- A series of experiments to demonstrate the physics and technical feasibility of laser acceleration
- Facilities are nearing completion, and await a final Accelerator Readiness Review on December 18th
- E163 facilities include:
  - A new single-pulse low-energy-spread electron source for the NLCTA
  - A 10 GW ultrafast laser system
  - A new shielded experimental enclosure which can be accessed while the NLCTA runs

• E163 will operate with beam ~60 hrs/month over the next 2-3 years testing laser-driven accelerator structure prototypes made by lithographic and fiber-drawing techniques

• The E163 facilities offer sub-picosecond electron and laser beams which are available to the broader user community for advanced accelerator experiments

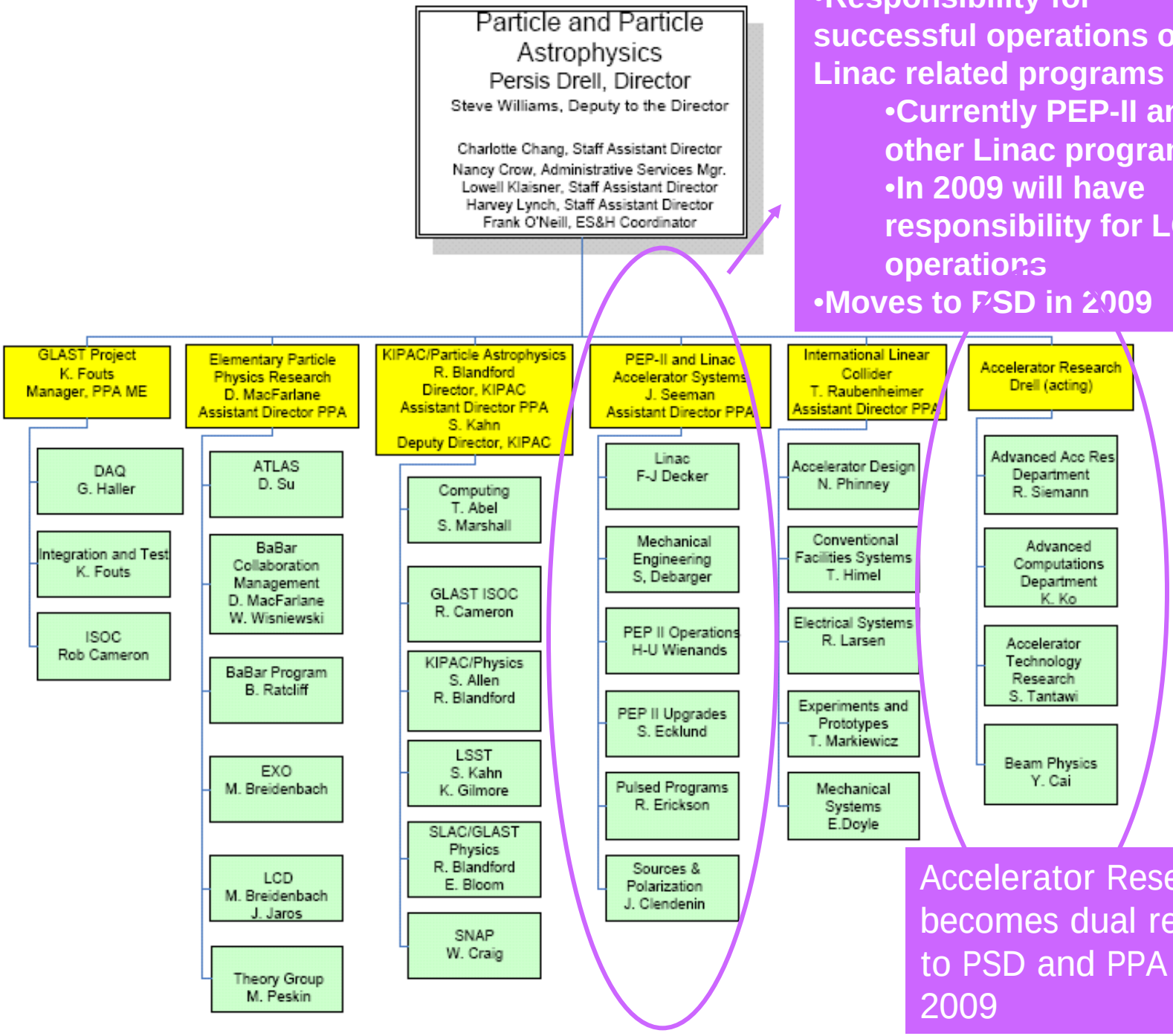
High Gradient Program at NLCTA

- NLCTA (3 RF stations, one Injector, one Radiation shielding)
  - Two 240ns pulse compressor, 300 MW peak, powered by two X-band 50 MW klystrons (used mainly for CERN and NLC type experiments)
  - One 400/200 ns pulse compressor, 500 MW peak, powered by 2 X-band 50 MW klystrons (Modulator is in final stage of construction, hopefully operational early next year)
  - 65 MeV injector with a 1 nC charge/bunch
  - Shielding enclosure suitable for up to 1 GeV
  - This system will be used to test novel rf accelerator structures and waveguide structures



High Gradient Program at ASTA (Klystron Test Lab)

- The facility comprises:
  1. Two 50 MW klystrons that can be combined
  2. A variable length pulse compressor that can produce up to 500 MW (under construction).
  3. When done (spring to summer of 2007) the facility will have the most agile RF system suitable for fast turn around of experiments.
- Programs intended for this facility:
  1. Scan the material for RF accelerator structures using the single cell accelerator structure technology as vehicle for these studies.
  2. Test Dielectric Accelerator structures in collaboration with ANL
  3. Test highly damped RF structures in collaboration with CERN and KEK
  4. Test superconducting materials and structures
- We started using ASTA and the Test lab facilities late this year. They are used for testing
  1. Superconducting materials (we tested various samples of niobium and magnesium diboride)
  2. Single cell accelerator structures (We tested our reusable universal couplers and our reference traveling wave accelerator structure)
  3. Dielectric accelerators in collaboration with ANL (test is under way for a quartz structure)



- Responsibility for successful operations of Linac related programs
  - Currently PEP-II and other Linac programs
  - In 2009 will have responsibility for LCLS operations
- Moves to PSD in 2009

Accelerator Research becomes dual report to PSD and PPA by 2009