SLAC: Present and Future

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Presented at the 2006 Annual Meeting of the SLAC Users Organization
SLAC's changing role

- Research directions are evolving dramatically
  - Balance of program elements and focus of effort are changing in substantial ways, following the imperative of fundamental physics questions that need to be addressed

- Photon science is rapidly expanding with LCLS and SPEAR3
  - In 2009, the major onsite accelerator-based facilities will both be primarily serving photon science

- Particle physics & particle astrophysics will remain an essential part of SLAC as a national laboratory
  - Will no longer be centered on a forefront onsite accelerator
  - Will most certainly be serving a broad national and international user community
    - Exploitation of the unprecedented BABAR data set
    - TeV-scale physics at the LHC and the ILC
    - Particle astrophysics at GLAST, LSST, and SNAP
    - Major non-accelerator efforts such as EXO
  - Will continue to pursue a vibrant accelerator research program
SLAC photon science future

- X-Rays have opened the Ultra-Small World—Realm of SPEAR3—Operating Now
  - $10^{12}$ photons/sec from high brightness undulator
  - Energies ranging from 400 eV to 40 keV
  - 50 ps pulse length
  - Limited coherence at x-ray wavelengths

- X-ray Lasers will open the Ultra-Small and Ultra-Fast Worlds—Realm of LCLS—First Light 2009
  - $10^{12}$ photons/pulse
  - Energies from 800 eV to 9 keV
  - 200 fs pulse length at commissioning, evolving to 10-30 fs within 1-2 years
  - Fully coherent at x-ray wavelengths
SPEAR3—a new machine
Linac Coherent Light Source (LCLS)

At turn-on in 2009: LCLS will be the world's first X-ray laser.
LCLS: remarkable opportunities for discovery

- Femtochemistry and biology
- Nanostructured materials
- Atomic physics
- Plasmas and warm dense matter
- Imaging of nanoclusters and single biomolecules
- X-ray laser physics
Stanford Linear Accelerator Center

Directorate Level Organization

Laboratory Director’s Office

Jonathan Dorfan
Laboratory Director

Keith Hodgson
Deputy Director

Persis Drell
Deputy Director

John Cornuelle
Chief Operating Officer

Director of LCLS Construction *
John Galayda

Director of Photon Science
Keith Hodgson

Director of Operations
John Cornuelle

Director of Particle and Particle Astrophysics
Persis Drell

* Reports directly to the Laboratory Director
Overview of Particle Physics and Particle Astrophysics Program
Exciting but challenging times

- **Excitement**
  - The Standard Model is fabulously successful, but...
    - Dark Matter and Dark Energy make up 95% of the Universe
    - We don’t understand why the Universe is matter dominated
    - We don’t understand the fundamental nature of the neutrino
  - Compelling questions confront us
    - Within this decade tools coming on line to make progress in our understanding
    - Developing tools for discovery in the next decade

- **Challenge**
  - Premier US HEP accelerators will turn off by the end of the decade and the frontiers of HEP will be off shore
  - Long term health and future of the field of HEP relies on ILC
    - Not a certainty! Timescale for physics end of next decade
  - Need to balance near, medium and long term priorities of the field
SLAC particle & astrophysics future

- Successful completion of B-Factory program
  - Highest priority for SLAC PPA Directorate
- Physics at the energy frontier
  - ILC, LHC, and fundamental accelerator research
- Investigations of dark matter and dark energy
  - GLAST, LSST, and SNAP
- Investigation of fundamental nature of the neutrino
  - EXO-200 and full EXO observatory
- All elements supported by strong program of theoretical investigations
Timelines for program elements

- **Science in the near future (now to 2012)**
  - BABAR operations to 9/2008, physics exploitation through 2012 or beyond
  - GLAST launch and science exploitation (2007-2012/2017)
  - TeV-scale physics at LHC with Atlas and LARP
  - Proof-of-principle experiments in accelerator research

- **R&D for mid-term physics (2012 and beyond)**
  - R&D for the ILC and LCD
  - Development of the LSST CCD camera design
  - Construction and operation of EXO-200 & development of Ba** for full EXO
  - Contributions to SNAP

- **R&D for long-term future (2020 and beyond)**
  - High-gradient accelerator program with SABER
  - Frontier accelerator research: laser, plasma-based techniques
B-Factory physics program

- **Present and future physics goals**
  - 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
  - Potential for discovery from large data sample across range of heavy quark and lepton flavor, two-photon and ISR physics

- **B-Factory program operates until end of FY2008**
  - Final upgrades to machine and detector during fall 06 shutdown

- **Ultimate goal: deliver to BABAR \(\sim 1\text{ab}^{-1}\) by end of FY2008**

**SLAC is committed to delivering B Factory luminosity**
# PEP-II luminosity records

## Peak Luminosity

<table>
<thead>
<tr>
<th>Luminosity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.069×10^{33} cm^{-2}sec^{-1}</td>
<td>August 16, 2006</td>
</tr>
<tr>
<td>1722 bunches</td>
<td>2900 mA LER</td>
</tr>
</tbody>
</table>

## Integration records of delivered luminosity

<table>
<thead>
<tr>
<th>Record Type</th>
<th>Luminosity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best shift</td>
<td>339.0 fb^{-1}</td>
<td>Aug 16, 2006</td>
</tr>
<tr>
<td>(8 hrs, 0:00, 08:00, 16:00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best 3 shifts in a row</td>
<td>910.7 fb^{-1}</td>
<td>Jul 2-3, 2006</td>
</tr>
<tr>
<td>Best day</td>
<td>849.6 fb^{-1}</td>
<td>Aug 14, 2006</td>
</tr>
<tr>
<td>Best 7 days</td>
<td>5.385 fb^{-1}</td>
<td>Jul 27-Aug 3, 2006</td>
</tr>
<tr>
<td>(0:00 to 24:00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best week</td>
<td>5.111 fb^{-1}</td>
<td>Jul 30-Aug 5, 2006</td>
</tr>
<tr>
<td>(Sun 0:00 to Sat 24:00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak HER current</td>
<td>1900 mA</td>
<td>Aug 15, 2006</td>
</tr>
<tr>
<td>Peak LER current</td>
<td>2995 mA</td>
<td>Oct 10, 2005</td>
</tr>
<tr>
<td>Best 30 days</td>
<td>19.315 fb^{-1}</td>
<td>Jul 19 – Aug 17, 2006</td>
</tr>
<tr>
<td>Best month</td>
<td>17.036 fb^{-1}</td>
<td>July 2004</td>
</tr>
<tr>
<td>Total delivered</td>
<td>410 fb^{-1}</td>
<td></td>
</tr>
</tbody>
</table>
Projected BABAR data sample growth

- Double data set from 2006 to 2008
- Integrated Luminosity [fb⁻¹]
- \( L_{\text{peak}} = 9 \times 10^{33} \)
- 4-month down for LCLS, PEP-II & BABAR
- ICHEP08
- PEP-II: 9xIR-2 vacuum chambers (including 2x new Q1/Q2 bellows), 2xrf stations, BPM work, feedback systems
- BABAR: LST installation

SLAC: Present and Future
Longer-term plans for BABAR

- **Post data-taking phase beyond 2008**
  - Physics analysis will continue at a vigorous rate for 2-3 years after end of data taking
    - Analogous to physics produced from summer 2004 data
  - Data sample will offer a long-term legacy beyond this, with an expectation that analysis will continue at a reduced level well into the next decade

- **Ideas for Super B Factories are vigorously pursued**
  - Physics case based on sensitivity to new physics in beauty, charm and tau sectors, as a complement to LHC discoveries
  - Mature Super KEKB proposal to upgrade KEKB to 4-8x10^{35}
  - INFN moving to prepare a design concept based on linear collider ideas for a new very high luminosity facility (>1x10^{36})
Planning for FY09 Transition

- In FY09, the B Factory will stop operations & LCLS will startup
  - The challenge we face between now and 2009 is the balancing B Factory and LCLS priorities
    - Issue was a focus at B Factory operations review this spring
  - We recognize this challenge, which is receiving active and aggressive management

- Transition planning well underway
  - Laboratory model for support of LCLS operations by OS/Basic Energy Sciences has been developed under leadership of Persis Drell and Keith Hodgson
  - Subject of a review this week by Office of Science

- Laboratory will grow between now and end of the decade
Atlas at the LHC
The Energy Frontier: LHC

- Participation in LHC accelerator research program (LARP)
  - Designing collimators for LHC & LHC upgrades
- SLAC now a member of Atlas
  - Four major areas of participation identified working closely with our Atlas university and laboratory colleagues
  - Growing efforts in HLT and DAQ, pixel detectors and tracking, GEANT4 and simulation, already having impact
  - Proposal for Tier 2 Center accepted and already being implemented
    - Supported by all west coast Atlas institutions and US Atlas community
    - Partnering with UCSC and LBNL to develop a strong west coast hub for Atlas physics exploitation
Arguments for SLAC entry into Atlas

✓ Allows exploitation of the physics synergy between LHC and ILC at the energy frontier
  o Direct involvement in both is best path to gaining a first-hand understanding of the full physics opportunity
  o ILC approval is now also tied to the initial outcome of LHC and its potential for new physics discovery

✓ After BABAR data taking & before physics at the ILC, there will be a significant gap in accelerator-based HEP
  o Joining LHC an obvious way of maintaining & developing a healthy work force for ILC, by continuing to attract the best young people to SLAC

✓ Responds to the needs of our user community
  o Supports traditional SLAC-University partnerships, now in the commissioning, operation, and physics exploitation of the LHC
  o Provides an avenue for other University user groups to join the LHC, while also working on BABAR, for example
SLAC areas of involvement

- With advice from Atlas and US Atlas managements, and many US/Atlas users, identified 4 related areas of initial contribution:
  - Pixel detector commissioning and calibration, based on experience at Mark II, SLD, & BABAR
  - Higher level trigger, building on extensive SLD & BABAR expertise
  - Core and Atlas-specific GEANT4 simulation
  - Tier 2 computing center & eventually a west-coast physics center in partnership with LBNL, UCSC, and the larger Atlas user community

- Roles are connected to each other, to our physics interests, and to our user community
- Consistent with likely roles on ILC detector as well

All areas with unique strengths at SLAC matched to a national laboratory role
Western Tier 2 center at SLAC

- Proposing to be a premier Tier 2 center = simulation, calibration & detector studies, and physics analysis
  - Good data access and strong technical support is crucial for analysis
  - Proposal supported and developed in conjunction with LBNL, Arizona, UCSC, UCI, Oregon, Wisconsin Madison, & Washington

- Will leverage existing & planned investments for BABAR
  - Investment level about 25% of typical BABAR computing needs
  - Proven management tools and scalable infrastructure
  - “Lights out” no operator 24x7 operation for last 10 years
  - Common CPU pool with BABAR can benefit both experiments by exploiting staggered peak usage
  - One incremental FTE systems/operations support person from Tier A; remainder of support directed to hardware purchases

- SLAC, in partnership with LBNL & UCSC, will help support a vibrant west coast center for physics on Atlas
  - Many common interests in Atlas: pixel and inner detector tracking/alignment, trigger and event simulation, & physics analysis
  - User facilities exist to house many visitors on site
  - New mode for HEP that we are keen to develop with our users
ILC machine & detector

See talks by Barry Barish, Jim Brau
The Energy Frontier: ILC & LCD

- Committed to the ILC as highest priority new facility for international particle physics
  - Broadly involved in all aspects of the ILC machine design and development
  - Partnering with university community in developing concept for detector

- Major focus of SLAC ILC effort as part of GDE coordinated effort
  - RF power sources, operational issues, particle sources, beam delivery system, machine-detector interface and instrumentation

- Developing ILC detector concept in partnership with university community
  - Focus on R&D for silicon tracking, particle-flow calorimetry, detector simulation, and overall detector concept
The ILC effort at SLAC

- Large and broad effort: 60 FTEs made up of about 80 people
- Four areas of major focus
  - RF power sources (modulators, klystrons, RF distribution)
    - Builds on core SLAC strength
  - Operational issues (highly available hardware, beam instrumentation, beam tuning techniques, and Machine Protection System)
    - Builds on experience from SLC and X-band R&D program
  - Particle sources (Polarized electron source and Positron source)
  - Beam delivery system and Machine-Detector Interface
    - Particle sources and Beam Delivery System utilize experience from the SLC and R&D for the X-band linear collider
    - SLAC has led these efforts for the linear collider over the last decade
LCD overall strategy

Factors driving development timeline
- Technical requirements require significant large-scale R&D to realize beyond state-of-the-art performance, e.g., $30\% / \sqrt{E}$ from particle-flow calorimetry
- GDE pursues an aggressive TDR goal by 2009
- Scale of European R&D effort significantly larger: Need to increase US effort to maintain intellectual leadership consistent with EPP2010 report

Strive to develop coherent detector design SiD with US and international partners
- Allows exploration of overall constraints and optimization
- Key element is particle-flow calorimetry, requiring dense, highly segmented SiW electromagnetic and hadronic calorimetry
- High magnetic field, compact tracking follow from cost considerations
Neutrinos—EXO

- Determining fundamental nature of neutrino with search for \(bb\text{on} \) decay in \(^{136}\text{Xe} \rightarrow ^{136}\text{Ba}^{++}e^-e^-\)
  - What is absolute mass scale for neutrinos?
  - Is the neutrino its own antiparticle?

- **Strategy:**
  - Currently building EXO 200 for installation at end of year
    - Study detector performance (no \(\text{Ba}^{++}\) tagging)
    - Sensitivity of \(~0.2\) eV to \(0\nu\beta\beta\) mode
  - Continue R&D on \(\text{Ba}^{++}\) tagging for next 2-3 years

- **Successful R&D would lead to proposal for full EXO (ton scale experiment)**
  - EXO goal: \(<m(v_e)> \sim 10\text{'s of meV}\)
See talk by Patric Muggli, John Seeman

Accelerator Research

| Phasespace x3x2x1 |
Time = 28.00 [1/\omega_p]
The energy frontier: accelerator research

- **Push the envelope with operating accelerators**
  - Supporting PEP-II and flavor factories worldwide
- **Study beam physics and develop accelerator technology for next generation facilities**
  - ILC, future multi-TeV linear colliders & high gradient research
- **Push the state-of-the-art in computational tools**
  - Bridging the gap between theory and technology
- **Explore advanced accelerator research in collaboration with university community**
  - Laser acceleration
  - Plasma wakefield acceleration
- **Exploit unique facilities**
  - Final-focus test beam (FFTB & soon SABER)
  - NLC Test Accelerator (NLCTA)
FFT B final experiments

- Final FFTB running shared between SpsS and Plasma wake-field experiment (E167)
  - End of the line for spectacular facility
  - Disassembled to make way for LCLS
- Spectacular results from final E167 run
  - Demonstrated 42GeV of acceleration in 1.2m column of plasma
  - Highest energy electrons ever made at SLAC
- SABER (FFT B replacement) in development
  - White paper outlining science case 11/05
  - Workshop with community 2/06
  - In discussions with DOE about funding and timeline
Particle Astrophysics and Cosmology

See talks by Roger Blandford, Ted Baltz, Tom Abel
Kavli Institute for Particle Astrophysics and Cosmology

Founded 2003
Director: Roger Blandford
Deputy Director: Steve Kahn
~120 members
Two new buildings, labs

Instrumentation, data analysis, particle astrophysics, relativity, computational astrophysics, observational cosmology, theoretical cosmology...

KIPAC is a major new opportunity for the SLAC user community
Particle astrophysics and cosmology

- Tremendous scientific opportunities to explore the dark universe, recognized as priority by EPP2010
- Large Synoptic Survey Telescope (LSST)
  - Best matched instrument for ground-based weak lensing measurements to use dark matter to map properties of dark energy
  - Focus on development of CCD camera & corresponding DAQ challenges as well matched to HEP experience
- Participation in Joint Dark Energy Mission
  - Partnering under leadership of LBNL in the SNAP concept
- Gamma Ray Large Area Space Telescope (GLAST)
  - Moving towards launch in fall 2007, with growing understanding of GLAST’s role in dark matter campaign
  - Center for scientific program (ISOC) based at SLAC
GLAST instrument status

- **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

- **Instrument is fully assembled**
  - Shipped from SLAC in May
  - Instrument level environmental tests in conducted at NRL

- **Environmental testing completed!**

- **On track for Fall 2007 launch**
  - In transit to be mated with launch vehicle
Summary of SLAC program

➢ An array of fundamental physics questions challenge our understanding of nature and the universe
  o EPP2010 maps out a strategy of leadership for the US program in addressing these questions
  o Central elements of this strategy are:
    • Full exploitation of the LHC
    • Development and eventually hosting of the ILC in the US
    • Pursuit of particle astrophysics experiments (GLAST, LSST, SNAP), a new round of coordinated neutrino experiments (EXO), full exploitation of BABAR and possible further exploration at Super B Factories

➢ SLAC PPA program recognized early on these scientific directions, as is already well aligned with national priorities
  o Actively planning a transition from onsite accelerator-based frontier research at BABAR to a portfolio involving major contributions to the international program at Atlas, SiD, and EXO, astro-particle physics (GLAST, LSST, SNAP) and potentially elsewhere
  o Science has and will continue to be the driver for this program, with SLAC continuing its role a strong partner and national user facility
Backup Slides
Resources will redistribute between programs

Consolidated after launch

To PSD in FY09

Programs will grow