Thoughts on the SLAC Future HEP Program

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Particle Physics and Astrophysics at SLAC

* SLAC was originally created as a high energy physics laboratory and has a long and distinguished history in this field.

* It has been the primary facility in the country for electron-based accelerator physics, and the use of electron and positron beams for particle physics research.

* The involvement in GLAST and the creation of the KIPAC in 2003 extended the general scope of research at the laboratory to include non-accelerator based experiments addressing key aspects of particle astrophysics and cosmology.

* High energy physics continues to be a vibrant area of research, and the management at SLAC is committed to retaining our leadership in this field. Some of the most profound and pressing questions in physics are likely to find answers in the next round of experiments, already in development.

However, SLAC's HEP program is clearly in transition…

* The B-factory will cease operations within the next month. For the first time in its history, SLAC will have no accelerator-based experiment in HEP running on-site.

* Stewardship of the laboratory has shifted from HEP to BES at DOE.

* The focus of global particle physics research will move to CERN with the turn-on of the Large Hadron Collider in 2008.

* The ILC, planned to be the next big facility for this field, faces significant and uncertain delays.

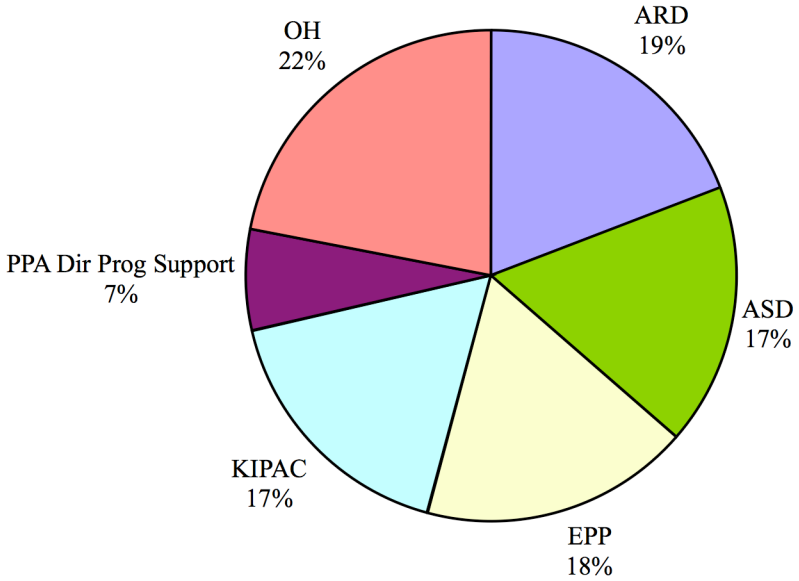
* The HEP budget was very tight in 2007. We took a major budget hit in 2008, and the situation is rather unclear for 2009 and beyond.

Current PPA Program

* In FY08, the PPA program is roughly equally balanced between research in three major fields of research: Elementary Particle Physics (EPP), Particle Astrophysics and Cosmology (KIPAC), and Accelerator Science (ARD).

* Another roughly equal share of the workforce and budget had been devoted to the final year of operating the B-factory (ASD), which has now been shortened considerably.

* The remainder goes to overhead and direct program support.

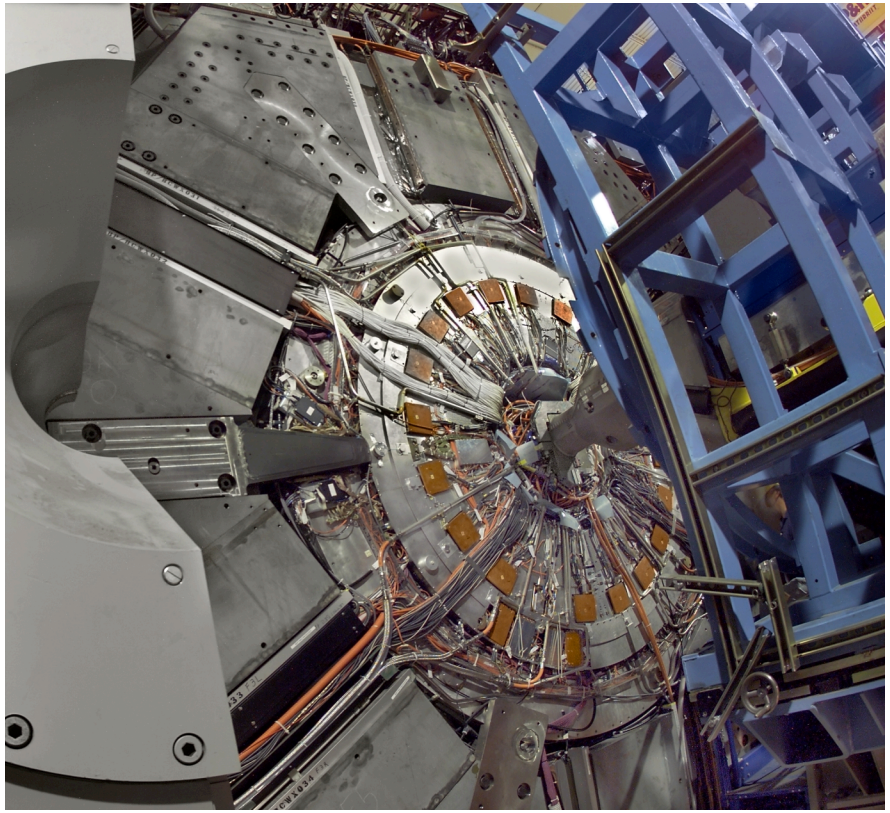


BaBar

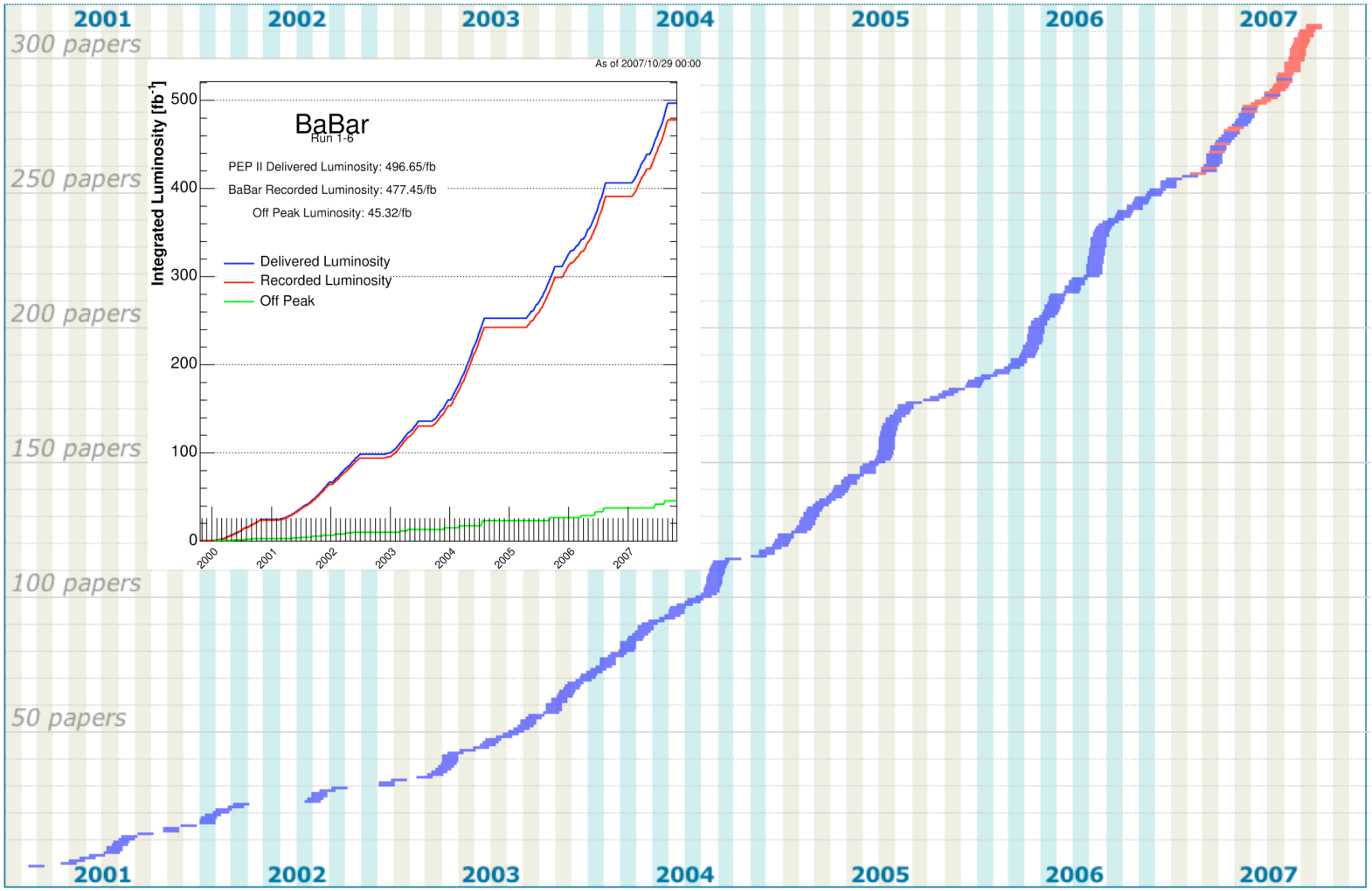
* BaBar has provided a highly constrained and redundant set of precision tests of weak interactions in the Standard Model.

* These, in turn, yield direct searches for physics beyond the Standard Model.

* With the recent budget cut for HEP, the final run of the B-factory has been shortened by six months.
  – BaBar has decided to use the time to provide unique data sets on the narrow resonances Y(3S) and Y(2S), rather than continue to add luminosity at Y(4S).



BaBar has been extremely productive scientifically.



Gamma-Ray Large Area Space Telescope

* The GLAST experiment will open up a new window on the universe when it is launched this coming May.
  - It will provide a factor of 50 improvement in sensitivity over previous experiments for the detection of gamma-ray sources at GeV energies.
  - SLAC played the lead role in the construction of the Large Area Telescope (LAT), the main experiment on the mission.

GLAST Science

* The SLAC scientific focus on GLAST has been in three main areas:
  - *Indirect detection of dark matter*.
    - WIMP annihilation at the galactic center and other dark matter concentrations can lead to detectable gamma-ray signals in the GLAST bandpass.
  - *Particle acceleration in cosmic sources.*
    - Shock acceleration in supernova remnants and gamma-ray bursts can accelerate particles up to PeV energies and higher. Understanding this process in detail has been at the center of cosmic ray astrophysics for 50 years.
  - *Relativistic outflows.*
    - Active galactic nuclei and other astrophysical sources produce relativistic outflows with prodigious mass loss rates. This is a core area of particle astrophysics research.

ATLAS

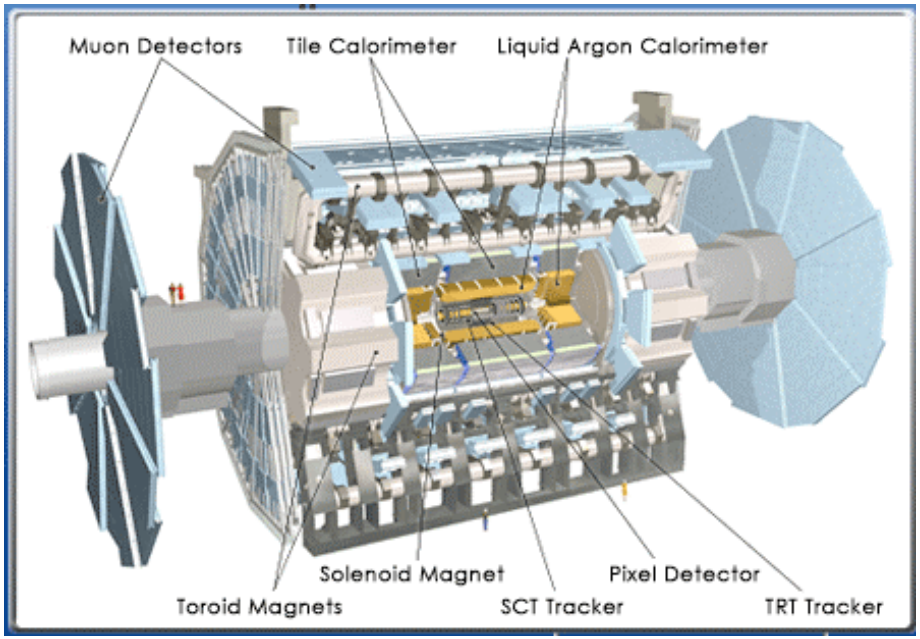
* SLAC joined the ATLAS experiment at LHC roughly 2 years ago.

* Key participation has been in the pixel detector commissioning, the higher-level trigger, and computing efforts.

* ATLAS is attracting excellent new talent to SLAC - 1 Panofsky Fellow, 3 Postdocs, 2 Graduate Students. We currently have an active search for an Assistant Professor.

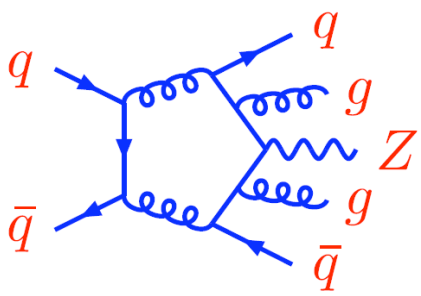
* We are hosting an ATLAS Western Tier 2 Center at SLAC, with the possibility of an even larger role in the future.

* We are partnering with UCSC and LBNL to form a very strong west coast hub for the ATLAS community.



Theory Group Efforts at SLAC are Strongly Coupled to LHC Physics

Standard Model processes like $pp \to Z + 4$ jets with $Z \to \nu\bar{\nu}$ (invisible) mimic missing energy + jets signals for supersymmetry, other models of new physics



- Precise estimates need one-loop QCD scattering amplitudes require thousands of complicated Feynman diagrams
- Better to construct amplitudes using their basic analytic properties: "unitarity-factorization bootstrap" method
- Main concepts in method established

  Bern, Dixon, Kosower, Phys. Rev. D71:105013 (2005); D73:065013 (2006); BDK + Berger + Forde, D74:036009 (2006); D75:016006 (2007); Forde, arXiv:0704.1835 [hep-ph]

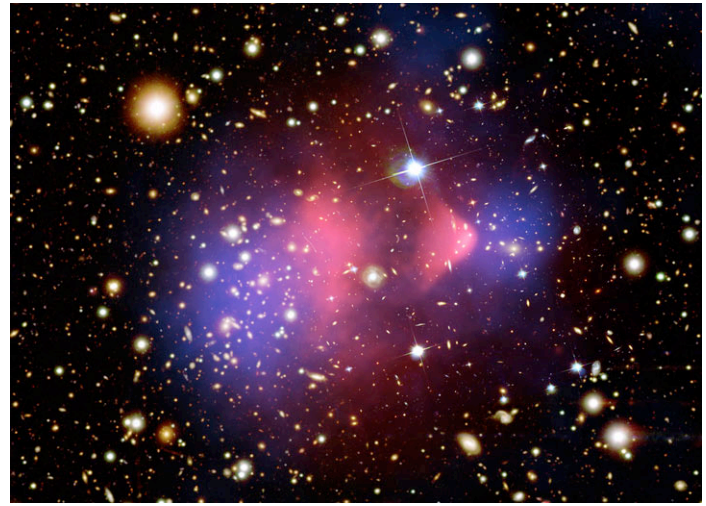
- Next steps will include much automation
- At SLAC: Dixon, Berger and Forde, with Maitre (just arrived) and Gleisberg (arriving in Fall)

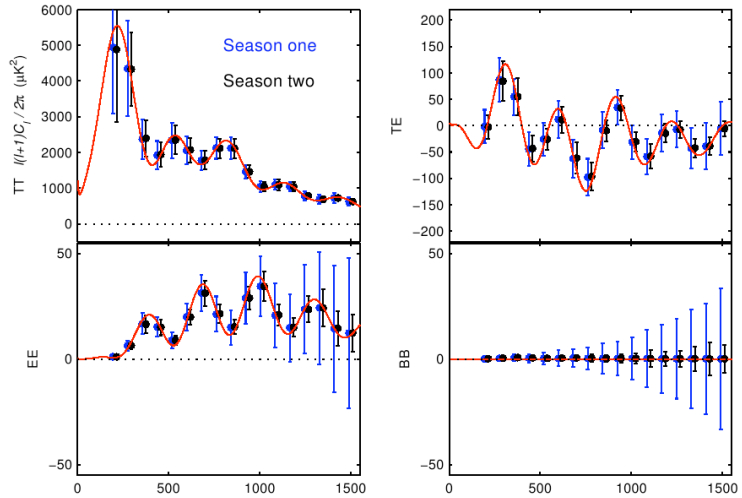
Kavli Institute for Particle Astrophysics and Cosmology

* KIPAC was created in 2003 as a joint institute between SLAC and the Physics and Applied Physics Departments at Stanford. There are currently 7 faculty members with joint appointments between PPA and Physics.

* The Institute has 39 Members, 18 postdocs, and 35 students, funded partly by SLAC and partly through campus accounts.

* KIPAC personnel are engaged in a wide range of theoretical, observational, and experimental research in particle astrophysics and cosmology





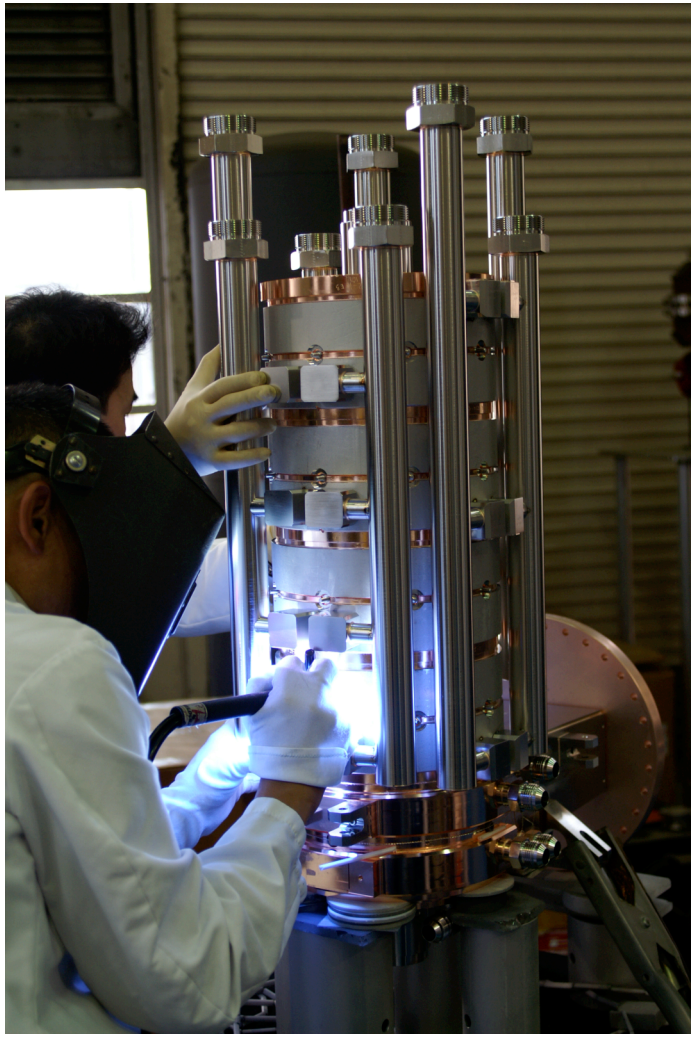
Accelerator R&D

* Accelerator physics is a major strength at SLAC
  - Internationally recognized R&D group

* There have been three main focus areas:
  - High gradient acceleration
  - Beam theory and accelerator design
  - High brightness beams and beam control

* Each area includes:
  - Near-term project support (LCLS and PEP-II),
  - Project R&D (ILC and LHC),
  - Long-term R&D (gradient and theory)

* There are applications across the lab



ILC Department

* SLAC played a major role in the generation of the Reference Design Report for the ILC.

* We offer unique expertise through our construction and operation of the only linear collider to date (Stanford Linear Collider):

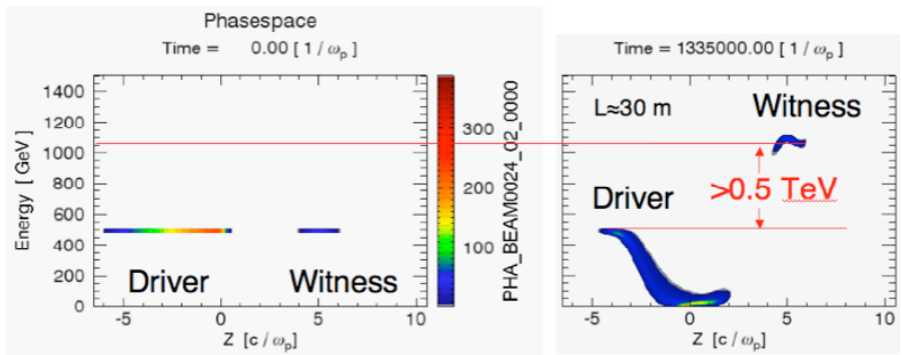
* We have led the R&D effort on rf sources and pioneering new technologies:
  - Marx generator modulators
  - Sheet beam klystrons
  - Advanced rf distribution systems and couplers

* We play key roles in the beam delivery systems, polarized electron sources, and linac design.

* Work in most of these areas has been curtailed in FY08 due to the severe budget hit to this program. But the workforce has been largely maintained, and we can start up again in FY09 if the budget allows.

Advanced Accelerator R&D

* Beyond the ILC, we are looking to new technologies to get to even higher energies:
  - High frequency rf accelerators (High Gradient Program)
  - Wakefield acceleration using plasmas or dielectrics
  - Laser driven plasma or dielectric accelerators
* Middle two topics and last topic are being investigated by AARD department
  - Acceleration gradients of ~50 GV/m (3000 x SLAC) in PWFA
  - ~1 GV/m in compact laser accelerator structures
  - FACET will provide a key new experimental facility at SLAC for advanced accelerator R&D



$N_D=3\times10^{10}$, $N_w=10^{10}$,
$\varepsilon_{Nx}=\varepsilon_{Ny}=2230\times10^{-6}$ m-rad, $\sigma_x=\sigma_y=15\ \mu m$, (beam matched to the plasma)
$\sigma_{zD}=145\ \mu m$, $\sigma_{zW}=10\ \mu m$, $\Delta z=100\ \mu m$
$N_e=5.66\times10^{16}\ cm^{-3}$, $L_p=30$ m

FACET Layout

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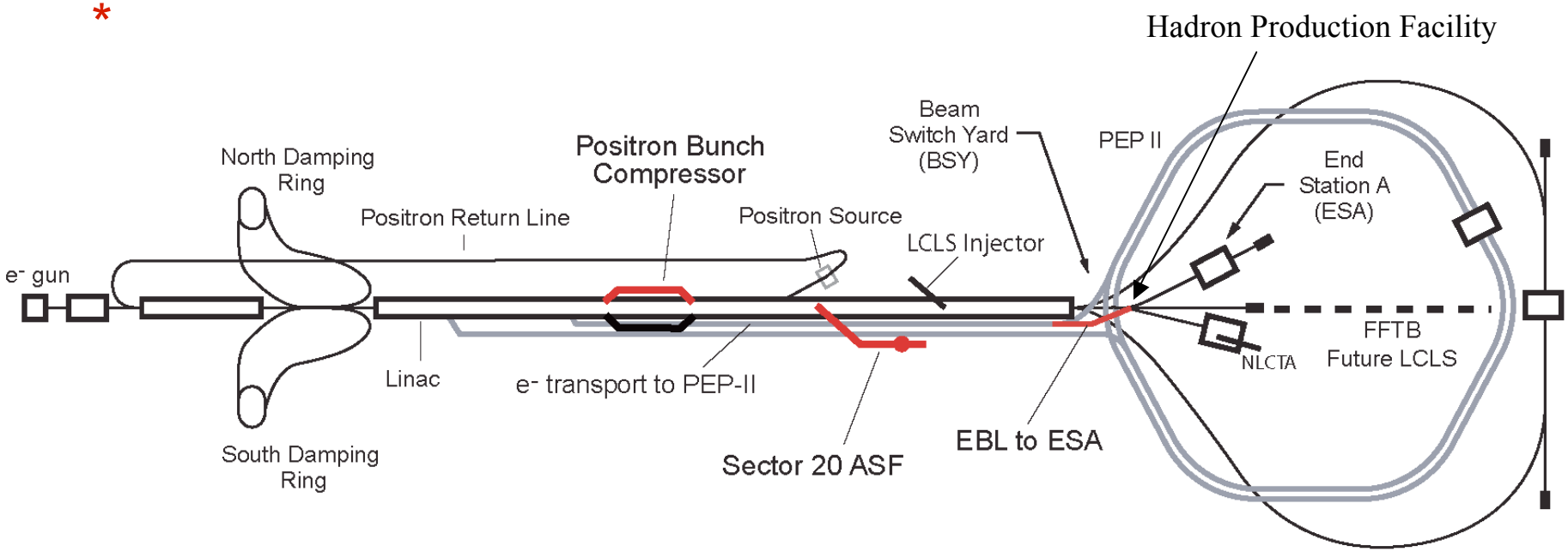

FACET has four areas:

Accelerator Science Facility (ASF) (Sector 20)

e+ bunch compressor (Sector 10)

Electron Bypass Line (EBL) extension to ESA

Hadron Production Facility in A-Line to ESA

The PPA Role in the SLAC Vision for the Future

* The Laboratory as a whole has been engaged in a strategic planning process since the beginning of this fical year. The vision that is emerging involves the continuation of a strong and vital program in high energy physics and related fields.

* Four of the "key science questions" that provide context for this vision fall in the general arena of HEP:
  - How did the Universe evolve to form the structure that we see today?
  - How do Nature's particle accelerators operate?
  - What new physics awaits us at the TeV scale?
  - What are the basic symmetries of Nature and how are they violated?

* In addition, two of the essential "enabling technologies" for the entire SLAC program, accelerator research and computational physics, will primarily be developed in PPA departments.

Some Guiding Principles on the Selection of New PPA Projects

* Keep overall balance between Particle Physics, Particle Astrophysics, and Accelerator Research. The vibrancy of each element and their strong interplay is one of our fundamental assets.

* Align with national priorities, as enunciated in the EPP2010 and P5 reports. In rank order, these have been:
  - Energy frontier.
  - Particle Astrophysics and Cosmology.
  - Neutrinos.
  - Flavor Physics.

* Maintain role for strong involvement by university-based user community.

* Recognize that we won't get everything we want. Generate viable backup plans that preserve the health of the program.

* Don't strive to maintain infrastructure for its own sake, but recognize the core competencies of the Laboratory and take account of their fragility in the face of funding uncertainties.

SLAC's Role as a User Lab?

SLUO
SLAC USERS ORGANIZATION

February 7th 2008 - SLUO Meeting

"Redefining the User Facility"

Agenda

07:30 - 08:00 - Breakfast

Chair: Michael Peskin
08:00 - 08:20 Gerard Bonneaud (Ecole Polytechnique & SLAC) - Introduction;
08:30 - 09:10 Steve Kahn (SLAC) - Draft P5 talk;
09:30 - 09:50 Greg Tarle (U Michigan, on the phone) [SLAC contact Aaron Roodman] - SNAP;

10:10 - 10:30 break

Chair: Tim Barklow
10:30 - 10:50 Ray Frey (U of Oregon) [SLAC contact John Jaros] - ILC detector R&D;
11:10 - 11:30 Gabriella Sciolla (MIT) [SLAC contact David MacFarlane] - DUSEL user base, including CDMS, EXO;
11:50 - 12:10 James Rosenzweig (UCLA) [SLAC contact Tor Raubenheimer] - ILC & advanced accelerator R&D;

12:30 - 1:30 catered lunch, general discussion - **convenor Chris Hearty**;

Chair: Steve Sekula
1:30 - 1:50 David Kirkby (UCI) [SLAC contact David Burke] - LSST;
2:10 - 2:30 Jason Nielsen (UCSC) [SLAC contact Su Dong] - ATLAS upgrade/computing/use support;
2:50 - 3:10 Rene Ong (UCLA) [SLAC contact Stefan Funk] - GLAST/TeV/UHECR;

3:30 - 3:55 break

Chair: Peter Tenenbaum
3:55 - 4:15 David Hitlin (Caltech) [SLAC contact Blair Ratcliff] - SuperB;
4:35 - 4:55 Sarah Church (SLAC KIPAC) - CMB polarization;
5:15 - 6:30 General discussion - **convenor Frank Porter**;

6:30 – 8:30 Breezeway Reception

Summary Statement from SLUO

Summation: The speakers pointed out a number of key features of SLAC which would be valuable to users even in the absence of an onsite experiment. These include the lab's computing infrastructure, engineering expertise and facilities, detector design and construction skills, competence in space-based experiments, beam facilities for accelerator research and for detector development via test beams, high density of excellent staff in a variety of fields, and experience in the management of extremely large projects. It was pointed out in discussions that SLAC dare not become a "job shop" in these capacities – that to ensure that the quality of the work performed at SLAC remains high, the SLAC scientific staff must be engaged in any project for which the laboratory provides these facilities. The selection of which projects SLAC will participate in must therefore balance the limits of the lab's capacity, the interests of the scientific staff, and the priorities of the field as a whole.

Finally, it appears from this meeting that for SLAC's users, as the National Academy EPP2010 committee concluded "…although setting priorities is essential, it also is critical to maintain a diverse portfolio of activities in particle physics, from theory to accelerator R&D to the construction and support of new experimental facilities…". Planning and maintaining such an ambitious enterprise, a national/international facility as SLAC appears to be up to now, is invaluable since SLAC will thus remain an ideal partner for university groups that do not have the facilities and the experienced manpower, and an appropriate interlocutor and a natural leader on the international arena.

Particle Physics: ATLAS and ATLAS Upgrades

* For the near-term future, the energy frontier will be accessed at the LHC. This is an extremely exciting opportunity for new physics discoveries. The SLAC effort to date has been excellent, but subcritical. We need to expand it to keep it stable.

* The establishment of the Western Tier 2 Center at SLAC has been strongly welcomed by university-based ATLAS groups with strong historical ties to the laboratory. We would like to see this emerge into an ATLAS analysis center, well coordinated with overall international collaboration, providing intellectual resources for physics analysis.

* The upgrade provides an excellent opportunity to take a leadership role in this experiment in the future. SuperLHC provides a vehicle for higher energy reach for new physics.

* Potential areas of activity:
  - Tracker upgrades
  - Simulation and optimization of the design and layout
  - 3-D pixel detector development, including FEE R&D
  - DAQ readout digital electronics
  - Higher-level trigger design

* Upgrade effort will build on strong working relationship with UCSC and LBNL, and will establish the Bay Area as a key ATLAS center in the U.S.

Particle Physics: Offshore SuperB Facility

* As you have heard, Italy is studying the construction of a SuperB facility with 100 times the luminosity the present B-factory.

* This will vastly improve the sensitivity for the discovery of quantum loop corrections to standard model processes, indicative of new physics at the TeV scale and beyond. Such data will be especially helpful to the interpretation of discoveries anticipated from the LHC.

* SLAC personnel have played leading roles in helping to define the requirements for such a machine, and the provision of parts from PEP-II and BaBar will dramatically reduce the cost of construction. US in-kind contributions to the project are essential to its viability, as will US accelerator and detector involvement should the project proceed.

* Discussions with Italian collaborators are on-going. We need to better understand the implications of this program for laboratory staffing on other programs. However, if a US role in SuperB is endorsed by P5, SLAC would certainly be eager to participate in this program.

Particle Astrophysics: The Large Synoptic Survey Telescope (LSST)

* LSST is our highest priority new particle astrophysics construction project at SLAC. It will produce a sample of 3 billion galaxies, suitable for deriving tight constraints on the properties of dark energy and dark matter through studies of the growth of structure with cosmic time.

* LSST is proposed as a joint NSF (Astronomy)/DOE (HEP) project, with DOE providing the 3 Gigapixel camera. The DOE effort is led by SLAC, with significant participation by high energy physics groups at other labs (BNL, LLNL) and at universities. There is also strong international participation by IN2P3 labs in France.

* The project will produce a several hundred Petabyte “open” database, which will be a gold mine for a wide range of astrophysical and cosmological investigations, supporting a very broad user community.

* LSST passed its CoDR from NSF in September, and is on track for an FY11 construction start. DOE/NSF negotiations will have to begin in January 2009 to maintain that schedule.

Particle Astrophysics: The SuperNova Acceleration Probe (SNAP)

* SLAC is a strong participant in SNAP as a candidate for the Joint Dark Energy Mission (JDEM), under discussion between DOE and NASA.

* SNAP will constrain the properties of dark energy via the use of Type 1a supernovae as calibratable standard candles, and weak lensing measurements as a probe of growth of structure.

* The project is led by LBNL, but SLAC has a major hardware role in the instrument control electronics and the fine guidance system. We believe we have unique experience to offer to this program through our involvement in GLAST. We are the only DOE-HEP laboratory to have played the predominant role in the construction of a major space mission.

* Scientifically, SLAC will provide leadership in the use of SNAP for strong lensing investigations.

Accelerator Science: ILC R&D Plus an Expanded High Gradient Program

* The eventual construction of a TeV-scale e+e- linear collider is the highest priority for high energy physics. At present, the ILC program remains the best available path to achieving that capability, and SLAC will maintain its vigorous involvement in the ILC program as it evolves.

* However, if the current ILC does not move forward as planned, we cannot give up the physics goal. Alternative technologies should be pursued to get us where we need to be in terms of cost and physics reach. Such technologies will also be crucial for moving beyond the ILC to get to higher energies.

* CERN is aggressively pursuing a high gradient, warm rf design based on two-beam rf power delivery (CLIC). They have made major advances in the design and testing of accelerator structures.

* SLAC leads a high gradient program in the US. We intend to expand this program, coordinated with efforts at CERN and KEK to further these warm rf technologies.

* Our principal focus will be in the design and development of alternative high power rf sources. Several new ideas have been suggested that could lead to major advances in this arena. We see this program potentially leading to the construction of a demonstrator facility on-site, e.g. a 3 - 6 GeV X-band linac.

Further Areas of Interest

* The program outlined in previous slides reflects our priorities for where we believe HEP-funded work at SLAC should proceed in the future. However, there are several other areas in which SLAC has strong interest and unique capabilities:

  – Underground Physics: SLAC is involved in EXO, and there is local leadership at Stanford in CDMS. We would hope to play a significant facilitating role in fielding major underground experiments at DUSEL, possibly in collaboration with LBNL and other laboratories.

  – Linear Collider Detector R&D: A vigorous program of basic detector R&D must be pursued in parallel with R&D on the machine. SLAC has been a leader in the SiD collaboration, and would expect to take a lead role in the development of this concept in the future.

  – TeV Gamma-Ray Astronomy: Following on GLAST, we see this field emerging as one of the more exciting areas for the future of particle astrophysics. SLAC is playing a leadership role in AGIS in its early stages.

  – Cosmic Microwave Background Research: As yet, DOE has not supported this field to any significant extent. However, it is well-coupled intellectually to the HEP program. Stanford has in-house expertise through the research programs of Church and Kuo.

What Fits?

* SLAC has had a declining HEP budget over the past few years because of the gradual transfer of responsibility for operation of the linac to BES.

* Our pre-omnibus FY08 budget was $120.5M. Post-omnibus, it was $95.4M. The President's budget for FY09 is $91.5M. Of this, ~ 20% is in support of residual B-factor operations (support for computing, D&D, etc.)

* If we assume that the 20% is maintained and is escalated out, that provides a wedge for new projects, in which case SLAC would occupy a "flat" fraction of a "flat" national HEP budget.

* Under that assumption, there are various scenarios that can be constructed. One such scenario allows us to take a key role in the ATLAS upgrade and SNAP, and take the leadership role in LSST and the construction of a future high gradient facility, while maintaining our basic research programs. If one or the other of these projects does not move forward, there could be room for some of the other efforts that I have mentioned. Going beyond this suite of projects would need some incremental commitment from the the national program during the construction phase.

What About Project X?

* We have been frequently asked, if Project X moves forward, will SLAC participate?

* Our priorities lie with the energy frontier and with particle astrophysics, following on the guidance from EPP2010 and our own interests and expertise.

* We have no objection to some aspect of Project X proceeding, if it does not preclude a strong U.S. role in LHC (including upgrades), a vigorous particle astrophysics program, and a healthy R&D program leading to a future TeV scale e+e- collider. However, we believe the priorities should lie in these other areas.

* There are scientists at SLAC interested in participating in Project X (both the machine and the experiments) if it is approved. We will try to support these roles to the extent we can, consistent with the prioritization stated above.

The "Cost" of Uncertainty

* I believe there is indeed a crisis in the field of high energy physics. However, in my view, it does not come from a lack of ideas for exciting new projects, or from the potential closing of major on-site facilities.

* Rather, I believe it comes from holding so many of our most promising new initiatives in "virtual status" for many years. It is hard to maintain enthusiasm among scientists and engineers working on these R&D efforts in the face of such uncertainty.

* SLAC is especially vulnerable in this context. Our major running and construction projects (BaBar and GLAST) are winding down. We have strategic decisions to make (who to layoff?, who to transfer to what efforts?, what areas of core competency to strengthen?, etc.) As indicated, we have a strong program of our own to put forward, but we must see it validated by the community and the agency in order for us to proceed.

* In my view, the most important thing P5 can do is to make "tough decisions". It is better in the long run to kill a project early then to leave it hanging indefinitely in a virtual state. We have many exciting programs on our plate. In fact, we have too many. Make decisions (hopefully based on physics), and let's move onward.

Summary

* Particle physics and astrophysics are alive and well at SLAC, and will be maintained as major components of the laboratory program even after the upcoming shutdown of the B-factory.

* SLAC is well-poised to take international leadership in key areas of the DOE-HEP program (dark energy, high gradient R&D) while growing its involvement in LHC.

* There are also opportunities for new areas of activity at the laboratory, which capitalize on our strong connection to Stanford programs (underground research, TeV gamma-ray, CMB).

* Not all of these programs will fit into a plausible funding scenario for the Laboratory. Guidance from P5 on priorities will be crucial for making this work.