PPA Strategy and Challenges

David MacFarlane
Associate Laboratory Director for PPA
June 11, 2010
Goals for the visit

• Morning:
  – Share PPA talk given to recent SLAC Science Policy Committee meeting, including X-band strategy [dbm]
  – Share our current thinking about future directions for the X-band rf program to generate discussion and feedback [Tor]

• Afternoon:
  – Resolve some remaining issues concerning FY2010 B&R allocations
  – Agree on a plan for use of carryforward to mitigate rise in indirects and computing recharge costs
  – Discuss and agree on a plan for GEANT4 core support and SPIRES
  – Pursue detailed discussions on X-band, SuperCDMS, or other open questions
Outline

• Overview of current PPA program
• Future initiatives
  – Energy Frontier: ATLAS & Linear Collider
  – Intensity Frontier: SuperB and EXO
  – Cosmic Frontier: LSST, SuperCDMS, CTA & CMB
• Concluding remarks
Rich science opportunities and a rich toolkit
Frontiers of particle physics and cosmology

- Guidance also from PASAG
- Report coming in September from ASTRO2010
SLAC Particle Physics & Astrophysics

- **Accelerator research:** ILC, high-gradient, plasma-wakefield, laser
- **Accelerator-based particle physics:** ATLAS & BABAR
- **Nonaccelerator physics:** EXO-200, CDMS
- **Astrophysics & Cosmology:** Fermi GST, DES

Engineering, DAQ, trigger & computing core capabilities

Particle, Astrophysics, & Cosmology Theory
Core research program breakdown by FTEs

FY2010, 288 FTEs, $73M core [$95M total + FACET]

Includes faculty, staff, postdocs, and students
Planning criteria

- Importance and impact of science opportunity
  - Includes long-term goals as a laboratory HEP effort
- Alignment with national priorities: HEPAP, P-5, PASAG, ASTRO2010, etc
- Coherence of overall PPA plan
- Match to current or future capabilities
- Availability of core research staff and/or faculty
- Responding to and supporting user community
Energy Frontier

Science Directions

Future energy-frontier accelerators

Higgs, SUSY, discovery physics

Accelerator research:
ILC, high-gradient, plasma-wakefield, laser

ACCELERATOR-BASED
PARTICLE PHYSICS:
ATLAS & BABAR

Nonaccelerator physics:
EXO-200, CDMS

ASTROPHYSICS &
COSMOLOGY:
Fermi GST, DES
ATLAS and the LHC

• National planning constraints
  – OHEP does not intend to grow LHC program beyond present levels
  – Growth plans at SLAC sharply curtailed as well, reduced even from FY2009 levels

• Revised timeline for the LHC and upgrades
  – Upgrade timeline unknown, CERN still evaluating options
  – No major DOE investments for coming 5 years at least

• Present focus
  – Proton research and M&O: Bringing detector into operation, computing support through Tier 2 center, initial physics exploitation, minimal near-term upgrade R&D
  – Detector R&D: generic longer-term upgrade R&D
Physics opportunities at the LHC

- Integrated Luminosity (fb⁻¹)

Year:
- 2008
- 2010
- 2012
- 2015
- 2018
- 2016
- 2018
- 2020

Not yet known

- 2016

SLHC

Current planning

SLAC

NATIONAL ACCELERATOR LABORATORY

PPA Strategy and Challenges
Next Energy Frontier machine: ILC

- International Linear Collider (ILC) R&D
  - Capable of 0.5-1 TeV
  - GDE plan for R&D and TDR development by 2012
  - Unlikely physics needs will be defined by then, nor is there an obvious host country
  - Reduced longer-term R&D effort thereafter, unless project launched

- Strengths: Mature design, proven technology
- Risks: High construction cost, limited energy reach
Next Energy Frontier machine: CLIC

• Compact Linear Collider (CLIC) R&D
  – Capable of multi-TeV energies
  – Collaboration with GDE on many systems & ILC detector community
  – CTF3 and CDR aimed at spring 2011
  – Further R&D and development of a TDR by 2016 (not yet approved)
  – May need large-scale systems test thereafter

• Strengths: Multi-TeV energy reach, lower construction cost

• Risks: Emittance preservation, two-beam rf source technology, high operating costs at multi-TeV
The LC-X Option & X-band Technology

• Provide a lower-cost expandable LC option
  – Develop a linear collider design aiming at 50% of ILC cost but with lower risk than CLIC design
  – 300~500 GeV LC option expandable to multi-TeV CLIC-like design

• Develop technology with broad application across OS
  – Low cost compact acceleration applications such as storage ring injectors, light source drivers, compact linacs for security, industry and medicine

• Core capability in rf and linac design
  – SLAC provides Office of Science (and the world) with a core capability in normal conducting rf linac design and fabrication

• Strengths: Understood rf source, lower construction cost, possible expansion pathway using CLIC approach

• Risks: Emittance preservation, not a recognized strategy by CERN or international community
Next Energy Frontier machine: Muon collider

• Enlarged R&D program proposed by Fermilab
  – Part of a long-term strategy building on high-power proton sources: Project-X, neutrino factory, and muon collider

• Major technical challenges to be addressed
  – Source: 8 GeV x 4 MW proton driver to create $10^{14}$ muons/s
  – Cooling: Muon capture and 6-D phase space cool by more than $10^6$
  – Acceleration: Collective effects due to bunch structure and muon decays
  – BDS: High-field superconducting focusing magnets and detector shielding

• Strengths: Reduced construction costs, multi-TeV energy reach, lower operating costs at multi-TeV

• Risks: Significant technology challenges, precision physics capability not demonstrated
One of several possible scenarios

- **ILC**
  - TDR
  - Extended R&D

- **CLIC**
  - CDR
  - TDR
  - Systems test
  - R&D & CDR development
  - Physics requirements: both 500 GeV and multi-TeV
  - Technology strategy
  - International project development
  - 500 GeV LC-X construction

- **LC-X**
  - R&D & CDR development

- **Muon collider**
  - R&D & CDR development
  - TDR & systems tests
  - Neutrino Factory

- **Neutrino Factory**

**Timeline**
- 2010
- 2012
- 2015
- 2018
- 2025

My supposition
Concerns about LC-X strategy

• Skepticism and pushback on X-band rf and LC-X R&D proposal from recent SLAC SPC meeting
• Is an HEP energy-frontier LC a viable motivation?
  – How real is the potential impact on cost (stated goal of 50%)?
  – Is there a realistic scenario where LC-X could be a factor in realizing a future LC?
  – Would the international community adopt LC-X as part of its overall strategy or isn’t this just a revival of the NLC?
• Are the wider set of applications outside HEP a convincing motivation for technology investment?
  – HEP as steward of generic accelerator development could be interested in X-band technology R&D of wide future applicability
  – How real are the compact FEL, injector and/or security applications?
Technology Development & Lepton Collider strategy

• Pursue development of warm x-band rf technologies of benefit to a wide set of generic applications including HEP
  – OHEP would need to review and assess potential investments

• Broaden program options beyond cold-rf for ILC
  – Enlarge partnerships with CERN, KEK to position US program for foreign hosted LC based on broad range of technologies
  – Consider LC-X design effort when path to LC becomes clearer

• Engage in muon collider R&D program
  – Help US community explore viability of this pathway for next generation energy frontier machine

• Pursue detector R&D and support benchmark capability for LC experiments
  – LC is a precision instrument and options need to be evaluated in a common physics and simulation framework
An X-band R&D funding strategy

Assumes bare-bones ILC R&D program
Ongoing SLAC ILC Program

- Core elements of SLAC ILC program
  - L-band rf development: Marx v1, v2 and DTI, couplers & rf distribution
  - High availability electronics and LC accelerator physics
  - MDI program and the ATF2 test facility

<table>
<thead>
<tr>
<th>With SuperB scenario</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDE Mgmt</td>
<td>326</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SLAC Program Mgmt</td>
<td>670</td>
<td>671</td>
<td>340</td>
<td>340</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Electron Source</td>
<td>893</td>
<td>799</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CESR-TA</td>
<td>491</td>
<td>494</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accel Physics</td>
<td>326</td>
<td>327</td>
<td>327</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>MDI Design</td>
<td>1,159</td>
<td>1,202</td>
<td>1,200</td>
<td>1,000</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>ATF2</td>
<td>1,220</td>
<td>1,101</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>HA Systems</td>
<td>718</td>
<td>435</td>
<td>400</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>HLRF design</td>
<td>6,512</td>
<td>4,997</td>
<td>4,250</td>
<td>2,500</td>
<td>2,000</td>
<td>1,000</td>
</tr>
<tr>
<td>SLAC ILC budget (bare-bones model)</td>
<td><strong>12,315</strong></td>
<td><strong>10,026</strong></td>
<td><strong>8,017</strong></td>
<td><strong>5,200</strong></td>
<td><strong>4,280</strong></td>
<td><strong>2,280</strong></td>
</tr>
</tbody>
</table>
Science Directions

Intensity Frontier

Expand accelerator luminosity frontiers

Nature of the neutrino

New physics properties from flavor sector

Accelerator research: ILC, high-gradient, plasma-wakefield, laser

Accelerator-based particle physics: ATLAS & BABAR

Nonaccelerator physics: EXO-200, CDMS

Astrophysics & Cosmology: Fermi GST, DES

PPAC Strategy and Challenges
The SuperB Project

- Opportunity to pursue discovery science complementing the LHC energy frontier explorations:
  - Measurements of the flavor couplings will allow a deeper understanding of the nature of any New Physics
  - Same measurements are sensitive to New Physics at energy scales 5-10 times direct production at the LHC
- Two projects under development: SuperKEKB in Japan & SuperB in Italy
- Opportunity to broaden the scope of the US experimental HEP program
- DOE & SLAC would have major enabling role for the SuperB project with in-kind contributions of PEP II & BABAR components
- Participation in an offshore Super B Factory was recommended in all but lowest budget scenario of the P-5 Report
Current SuperB approval status & next steps

- Assessment requested by DOE/OHEP on possible US involvement in the INFN-hosted SuperB project
  - SLAC-led task force developed scenarios for new detector and new collider contributions beyond reuse of PEP-II/BABAR hardware
- Decision by the Italian government on approval of the SuperB project is expected imminently
  - SuperB designated as highest priority for funding under new National Research Plan announced by Ministry of Education & Science
- OHEP conducting comparative review of SuperB, SuperKEKB and g-2 flavor physics options this summer
  - Potential flavor physics investments for inclusion in FY2012 budget
Challenges

• Issues:
  – Development of a SuperB project team for an ambitious and technically challenging machine
  – Limited new investment being considered, perhaps below a level with enough impact on project success
  – Size of SLAC effort would be comparatively modest, leaving overall accelerator-based particle physics relatively small
  – Cannot sustain SLAC effort beyond FY2010 without a decision
  – Could consider SuperKEKB should SuperB fail to materialize, but no benefit from reuse of PEP-II & BABAR components in this case
An X-band R&D and SuperB funding strategy

Assumes bare-bones ILC R&D program
Enriched Xenon Observatory (EXO-200)

- Search for neutrinoless double beta decay in 200 kg of $^{136}\text{Xe}$
  - Occurs if neutrinos are Majorana & lepton number violated
  - Rate is proportional to $<m_\nu>^2$
- EXO-200 currently being set up at WIPP
  - TPC is in its cryostat
  - Should be taking data with natural xenon by late summer of 2010
Development of full EXO

• Results from EXO-200 critical in guiding strategy for ton-scale full EXO at DUSEL
  – No signal would lead to further work on liquid options
  – Observation of a signal would strongly push the design towards a gaseous detector

• Challenges
  – DOE/NP recently designated as the steward for DUSEL neutrinoless double beta decay experiments
  – Costs and technical risks of scaling to ton-sized liquid or gaseous underground detector
  – Other competing technologies may be adopted for next generation experiment
Science Directions

Cosmic Frontier

Accelerator research: ILC, high-gradient, plasma-wakefield, laser

Accelerator-based particle physics: ATLAS & BABAR

Nonaccelerator physics: EXO-200, CDMS

Cosmic dark matter & cosmic rays

Direct dark matter searches

Astrophysics & Cosmology: Fermi GST, DES

Inflation

Dark Energy
Large Synoptic Survey Telescope

- LSST is planned as a collaborative NSF and DOE-HEP project
  - NSF provides the telescope & data system
  - DOE the 3.2 Gigapixel camera
- SLAC led consortium developing the key camera technologies
LSST evolution & challenges

• Challenges:
  – LSST may not emerge with highest priority from ASTRO2010
  – Developing multiagency international funding for camera system
  – Building up sufficient scientific and technical team
  – Technical challenges in the camera and data management areas
Evolution of dark matter program: SuperCDMS

• SuperCDMS at the Soudan Mine: 15 kg
  – Joint NSF-DOE project
  – Currently discussing deployment of improved Germanium sensors (iZIP)

• SuperCDMS at SNOLAB: ~100 kg
  – Currently in the R&D Phase, expecting a CD-0 this year
  – SLAC plans to play a major role in the project

• GEODM at DUSEL: ~1000 kg
  – Currently in R&D Phase: S4 award from NSF for preliminary studies

• PASAG recommended direct dark matter experiments with high priority
  – Two 2nd generation experiments and the 100kg SuperCDMS SNOLAB experiment should be started as soon as possible
SuperCDMS R&D at SLAC

• Key areas of investigation include [LDRD + KA13]:
  – Procurement of crystals of large diameter (4 and/or 6 inch)
  – Optimization of fabrication process for large diameter sensors
  – Modification of laboratory equipment for large diameter sensors
  – Sensor development and quality control
  – Streamline testing with new cryogenic set-up
  – Support develop of tower mechanical structures
  – **Develop scalable software framework**
    • System architecture, data access, data processing and database middleware
  – Develop Ge Crystal Monte Carlo simulations within Geant4
  – Support deployment of test facility at SNOLAB capable of testing large diameter sensors
  – Systems engineering and management
CDMS timeline

- 2010: Concept for GeoDM at DUSEL (1T)
- 2012: R&D for SuperCDMS at SNOLab (100kg)
- 2014: Fabrication & assembly of SuperCDMS at Soudan (15kg)
- 2016: Operation
- 2018: Operation
Challenges

• Issues:
  – Other competing technologies could prove more effective at ton scale
  – Limited SLAC experience with germanium sensors, cryogenic systems, underground construction
  – CDMS Collaboration transitioning from University-style R&D efforts to full-scale projects
  – Fermilab has managed CDMS, SuperCDMS at Soudan; SLAC project management role uncertain
Advanced Gamma-ray Imaging System (AGIS)

- Next-generation ground-based γ-ray observatory
  - Based on an array of Atmospheric Cherenkov Telescopes
- 10x increase in sensitivity versus current experiments
  - Large area, fine angular resolution, improved background rejection
- Timeline
  - R&D and prototype ~2015

FY09 & FY10 LDRD funding
B-mode polarization of CMB background

• Probe energy scale of inflation; constrain sum of neutrino masses
  – Still need 1-2 orders of magnitude improvement in sensitivity
• Next-generation ground-based CMB arrays
  – BICEP/BICEP-II → Keck array → POLAR-1/POLAR array
    bolometer-based detection
  – QUaD → QUIET-1/QUIET-2 radiometry-based detection
• Timeline
  – Will likely remain small scale projects through ~2015

FY09 & FY10 LDRD funding
FY11 LDRD requested
Energy Frontier
Intensity Frontier
Cosmic Frontier

Snapshot in 5 years

Accelerator research: SuperB, LC, high-gradient, plasma-wakefield, laser

Nonaccelerator physics: EXO-200, SuperCDMS

Accelerator-based particle physics: ATLAS, SuperB

Astrophysics & Cosmology: Fermi GST, LSST
Snapshot in 5 years

Energy Frontier
Intensity Frontier
Cosmic Frontier

Accelerator research:
SuperB, LC, high-gradient, plasma-wakefield, laser

LHC upgrades, Project-X

Nonaccelerator physics:
EXO-200, SuperCDMS

ACIS

Accelerator-based particle physics:
ATLAS, SuperB

ATLAS upgrades

GeoDM

Astrophysics & Cosmology:
Fermi GST, LSST

LC demo, FACET phase II

PPA Strategy and Challenges
What ifs?

• What if X-band program is not pursued?
  – Future of X-band core competency threatened

• What if LSST is not pursued?
  – Other Dark Energy projects will be pursued, e.g., JDEM, Big BOSS, Euclid,…

• What if SuperB is not pursued in Italy?
  – Consider SuperKEKB, enhance LSST, SuperCDMS efforts, advance AGIS earlier
  – Accelerator-based particle physics focused only on ATLAS

• What if CDMS is not pursued beyond SNOLab?
  – Will have established a dark matter science group well positioned for PASAG-recommended next generation experiment
Parting questions

- Are the science questions being addressed appropriate?
- Is this program ambitious enough for Stanford and SLAC?
  - Challenging times for HEP as a field and discovery science generally in the US
- Will this program provide sufficient long-term direction?
  - Many projects are proposed but not yet funded
- Are planning assumptions sound?
  - Timescales, national priorities, and technical directions and trends
- Is the lack of a Project-X science engagement a problem?
- Do we have the staff to execute the plan? or can we attract the necessary talent?
Backup
Experimental core competencies

• Electronics engineering
  – System architecture, analog and digital front-end design, ASICs, high-performance DAQ systems, high-reliability systems, mechanical integration, hardware and software trigger systems, control systems

• Mechanical engineering
  – Low background materials & design, systems design, project management

• Computing
  – Online and offline systems, large-scale data management, detector simulations, state-of-the-art database systems

• Detector R&D
  – Silicon device design and fabrication, tracking systems, photodetectors and Cherenkov systems
ARD core competencies

- Beam theory
- Advanced acceleration R&D
- rf design and fabrication
- Accelerator design
  - Presently have world class programs in beam delivery system design; polarized e-source design; low emittance ring design; linac systems design; FEL design; & diagnostics
  - Working on designs for future SLAC facilities (LCLS-II, PEP-X) and facilities worldwide (ILC, CLIC, PS2, Super-B)
- Accelerator commissioning – LCLS, SPEAR-III, LHC