The Future of SLAC Particle Physics and Astrophysics

David MacFarlane
Associate Laboratory Director for PPA
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Rich science opportunities and a rich toolkit
Astrophysics and Cosmology

- Leading particle-astrophysics and cosmology:
  - Operating the Fermi Gamma-Ray Space Telescope and continuing scientific discoveries with this unique observatory

Mapping the high-energy gamma-ray universe with exquisite precision

See talk by Nicola Omodei
Frontiers of particle physics and cosmology

- Guidance also from Particle Astrophysics Scientific Assessment Group
- Guidance from Decadal Survey ASTRO2010

From the P-5 HEPAP Subpanel Report, May 2008
The Future of SLAC Particle Physics and Astrophysics
Science Directions

Future energy-frontier accelerators

Higgs, SUSY, discovery physics

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

Accelerator-based particle physics: ATLAS & BABAR

Particle astrophysics: EXO-200, CDMS

 Astrophysics & Cosmology: Fermi GST, DES

The Future of SLAC Particle Physics and Astrophysics
Overall data taking efficiency (with full detector on): 95%
Event display shows uncalibrated energies

$p_T(j_1) = 420$ GeV
$p_T(j_2) = 320$ GeV

Highest-mass di-jet event observed so far: $M_{jj} = 2.55$ TeV

From Fabiola Gianotti’s ICHEP2010 talk

See talk by Beate Heinemann
ATLAS effort at SLAC and the LHC

• National planning constraints on LHC program growth
  – OHEP does not intend to grow LHC program beyond present levels
  – Growth plans at SLAC sharply curtailed as well, but still a central part of our particle physics program with ~25 FTEs

• Revised timeline for the LHC and upgrades
  – Current LHC planning pushes high-luminosity program to 2020
  – No major DOE upgrade investments for coming 5 years at least

• Present focus of SLAC effort
  – Proton research and M&O: Bringing detector into operation, computing support through Tier 2 center, working with US ATLAS community on initial physics exploitation, near-term upgrade R&D
  – Detector R&D: generic longer-term upgrade R&D for high luminosity
Next Energy Frontier machine

- Strong partner in International Linear Collider (ILC) R&D
  - GDE plan for R&D and TDR development by 2012
  - Reduced longer-term R&D effort thereafter, unless project launched
- High gradient research pursued in conjunction with CERN’s Compact Linear Collider (CLIC) effort
  - Collaboration with GDE on many systems & ILC detector community
- Participant in Muon Collider R&D program led by Fermilab
  - Part of Fermilab’s long-term strategy building on high-power proton sources: Project-X, neutrino factory, and muon collider
  - Major technical challenges to be addressed
- Exploring other warm rf strategies with CERN, KEK
  - Physics or cost may drive international community to consider a broader approach to energy frontier lepton colliders
The LC-X Option & X-band Technology

• Provide a lower-cost expandable LC option
  – Develop a linear collider design aiming at a substantially lower 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, FEL 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

• Opportunities
  – Understood rf source, lower construction cost, possible expansion pathway using CLIC two-beam approach for higher energies
Developing X-band structures & sources program

5-10 years
Transformational research in structures

2-5 years
Structures and sources development

0-2 years
Developing industrial capability

Continuum: research leads to development leads to applications

Expansion of national HG effort

Keystone for R&D effort

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Plasma Acceleration: 1000x present gradients

- **FACET**
  - Demonstrate feasibility for controlled electron/positron bunch acceleration
- **Future**
  - 50 GV/m linear collider or compact radiation source

![Simulation of 25 GeV PWFA stage]

Defocusing
Accelarating
Decelerating ($E_z$)
Accelerated Witness Bunch
Drive bunch
Witness bunch
Drive beam

See talk by Tor Raubenheimer
Future lepton collider detector program

- HEP labs have developed a white paper on physics and detector R&D at lepton colliders shared with the DPF
  - Advocates a common program across lepton collider efforts
  - Argues that the broad physics goals of any lepton collider are similar, even if operational conditions are very different
  - Argues that we will need an objective comparison of the options as part of the process for defining an overall lepton collider strategy
  - Argues that this approach allows each effort to benefit from progress and accomplishments in the others
  - Argues that this approach ensures work is done in a coherent, efficient and cost effective way
  - Argues that this approach will help define detector R&D needs and priorities
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

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Next generation flavor physics: Super B Factories

• 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

• Recent DOE review of possible new intensity frontier investments will guide the next steps

See talk by Mike Sokoloff
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 fall of 2010
Science Directions

Cosmic Frontier

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

Particle astrophysics: EXO-200, CDMS

Accelerator-based particle physics: ATLAS & BABAR

Astrophysics & Cosmology: Fermi GST, DES

Direct dark matter searches

Cosmic dark matter & cosmic rays

Dark Energy

Inflation
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
Present: Sloan Digital Sky Survey

7.5 arcminutes
Future: LSST simulation

2800 galaxies $i < 25$ mag

7.5 arcminutes
Future: LSST simulation

LSST probes Dark Energy in multiple ways

- Cosmic shear (growth of structure + cosmic geometry)
- Counts of massive structures vs redshift (growth of structure)
- Baryon acoustic oscillations (angular diameter distance)
- Measurements of Type 1a SNe (luminosity distance)
- Mass power spectrum on very large scales tests CDM paradigm
- Shortest scales of dark matter clumping tests models of dark matter particle physics

2800 galaxies $i<25$ mag
Future: LSST simulation

2800 galaxies $i<25$ mag

Dark Energy
Equation of state

$$w = w_0 + (1-a)w_a$$
$$a = (1+z)^{-1}$$
LSST evolution

• DOE camera team
  – SLAC managed consortium, including BNL and university groups
  – Significant R&D and vendor development effort on the last several years
  – Camera integration and assembly would occur at SLAC

• Recent developments:
  – Recommended by NRC Decadal Survey (ASTRO2010) with highest priority for DOE & NSF funding
  – Exploring international funding contributions along with DOE for camera system in context of NSF-led overall project
  – Continuing to build up scientific and technical team
  – Addressing technical challenges in the camera and data management areas with R&D effort
Possible LSST timeline

Construction/MREFC
Commissioning/Operations

FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20 FY21

CD-0 CD-1 CD-2 CD-4

$M

DOE camera costs
NSF costs
Other funding

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Evolution of dark matter program: SuperCDMS

- HEPAP subpanel (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 evolution

• Project organization
  – Fermilab overall project lead, with SLAC taking on Germanium Tower System, Software & Computing, and supporting role on Project Management

• Recent developments:
  – Focusing on developing on SLAC experience with germanium sensors & cryogenic systems, and underground construction
  – Along with Fermilab, helping CDMS Collaboration transition to large-scale project planning
  – DOE planning a generic CD-0 for dark matter and we are discussing the scope of the next generation SNOLab experiment

See talk by Eduardo Do Couto E Silva
Ideal CDMS timeline

- 2010
  - Fabrication & assembly of SuperCDMS at Soudan (15kg)
  - Operation

- 2012
  - R&D for SuperCDMS at SNOLab (100kg)
  - Fabrication & assembly
  - Operation

- 2014
  - Concept for GeoDM at DUSEL (1T)
  - R&D
  - Sensor fabrication
  - Assembly
  - Operation
AGIS

Sensitivity to annihilation cross-section

• Next-generation ground-based $\gamma$-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

Advanced Gamma-ray Imaging System (AGIS)

Now CTA
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
The Future of SLAC Particle Physics and Astrophysics

Snapshot in 5 years

**Energy Frontier**
**Intensity Frontier**
**Cosmic Frontier**

**Particle astrophysics:**
- EXO-200
- SuperCDMS

**Accelerator research:**
- Super B
- LC
- High-gradient
- Plasma-wakefield
- Laser

**Accelerator-based particle physics:**
- ATLAS
- Super B

**Astrophysics & Cosmology:**
- Fermi GST
- LSST
Snapshot in 5 years

**Particle astrophysics:**
- EXO-200
- SuperCDMS

**Intensity Frontier**
- ATLAS upgrades
- Super B

**Energy Frontier**
- ATLAS upgrades
- Super B

**Cosmic Frontier**
- GeoDM
- AGIS
- CMB

**Accelerator-based particle physics:**
- ATLAS
- Super B

**Accelerator research:**
- Super B, LC, high-gradient, plasma-wakefield, laser

**LC demo, FACET phase II**

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