Report from the NSF

Joe Dehmer
Division of Physics

SLUO Annual Meeting
September 18, 2008
TOPICS

• Basic Information on the Division of Physics
• DUSEL
• The Economics of Basic Research
Scope and Budget* of PHY

Division of Physics

- AMOP Physics
- Elementary Particle Physics
- Part. & Nucl. Astrophysics
- Physics Front. Centers
- Theoretical Physics
- Nuclear Physics
- Biological Physics
- Physics @ Inform. Front.
- Gravitational Physics
- Education & Interdisc. Res.

*$250M + MREFC
PHYSICS* FRONTIERS, *circa 2008*

- Bose-Einstein Condensates, Atom “Lasers”
- Dark Matter, Dark Energy, Cosmology
- Gravitational Waves (GW), GW Astronomy
- New Fundamental Particles and Laws > TeV
- $\nu$ physics and $\nu$ astrophysics
- String Theory, Branes, Duality, Quantum Gravity
- Quark-Gluon Plasma, Supernova Dynamics
- Ultra-Fast, Ultra-Intense Laser Fields
- Cyberscience, Quantum Information Science
- Biophysics of Single Molecules, Cells, Networks
- Complexity, Emergent Behavior

* CMP in Division of Materials Research
Ten-Year Funding History

MPSSStability Funding
(Dollars in Millions)

FY98 FY99 FY00 FY01 FY02 FY03 FY04 FY05 FY06 FY07 FY08

DMR PHY CHE AST DMS CMA
Budget sectors over time

Core vs Centers vs Facilities

Fiscal Year

% PHY Budge


- core
- centers
- facilities
Personnel on Awards (FY 05)

- Senior Personnel 969
- Active awards 664
- Postdocs 536
- Other Professionals 370
- Graduate Students 997
- Undergraduate Students 419*

*Plus about 500 at REU Sites
DUSEL – What Is It?

- DUSEL is an underground laboratory supporting unique science and engineering research.
- The primary motivation has been for fundamental physics research, exploiting the shielding from cosmic rays.
- DUSEL, if approved, would be the world-leading underground laboratory, resulting in transformational and innovative streams of research.
Cosmic Questions for DUSEL

• Of what is the Universe made?
• What is Dark Matter?
• What are neutrinos telling us?
• Where did the antimatter go?
• Are protons unstable?
• How did the universe evolve?
DUSEL Physics Experiments

• The aforementioned questions are addressed at DUSEL via a variety of experimental probes:
  – Direct Detection of Dark Matter
  – Neutrino-less Double-Beta Decay
  – Nuclear Astrophysics
    • Accelerator-based cross-section measurements
  – Solar Neutrinos
  – Long Baseline Experiment, Proton Decay, and Supernovae Remnants (Mega-Detector)

DUSEL MREFC funding would support the construction of forefront experiments in nuclear- and astro-physics, and in particle physics using the Fermilab accelerator as a high intensity neutrino source.
Why DUSEL?

“A national underground laboratory offers the United States some vital scientific opportunities that will affect a number of important international efforts and provide a center in the United States for some of the most exciting physics at the beginning of the 21st century.”

» From “Neutrinos and Beyond”

The community is now detailing the case.
Community Planning Activities & Reports

- **Community Activities, Advisory Committee Reports**
  - Bahcall report (2001)
  - International Workshop on Neutrinos and Subterranean Science (NESS, 2002)
  - The Neutrino Matrix (Four APS Divisions, 2004)
  - Particle Physics Project Prioritization Panel (P5): A Strategic Plan for the Next Ten Years (2008)

- **National Research Council, National Science and Technology Council Reports**
  - Connecting Quarks to the Cosmos (2003)
  - Neutrinos and Beyond (2003)
  - Revealing the Hidden Nature of Space and Time (*EPP2010*, 2006)
DUSEL Solicitation Process

- Solicitation 1 (S1): define site-independent science scope and infrastructure needs; unify the community (awarded Jan 2005).
- Solicitation 2 (S2): develop conceptual designs for one or more sites (two awarded, Sep 2005).
- Solicitation 3 (S3): facility design for an MREFC candidate (one awarded – Homestake, U.C. Berkeley).
  - $15M total over three years, starting in September 2007.
- Solicitation 4 (S4, in clearance): technical designs for candidates for the DUSEL suite of experiments.
  - $15M total over three years.

S3 & S4 enable costs to be estimated for infrastructure, experiments & operations.
Solicitation 3: DUSEL Site Selection

• Goal was to select single site and team to develop technical design of facility.
• Four proposals were reviewed by multidisciplinary 22-member expert panel.
• Review included site visits & reverse site visits.
• Panel unanimously voted by secret ballot to recommend the Homestake proposal to the NSF for funding. NSF concurred.
• Cooperative agreement to University of California, Berkeley in Sep 07. Total award $15M over 3 years.
DUSEL  Deep Underground Science and Engineering Laboratory  at Homestake, SD

- Six and a half Empire State Buildings for scale
- Shallow Lab
- Mid-level
- Deep Campus
- Engineering
- Geoscience
- Biology
- Physics
- Astrophysics

NSF
Status of Sanford Laboratory

- SDSTA holds $124M for development of Sanford Laboratory.
  - $70M private benefactor (Sanford), $44M state SD, $10M HUD.
- Will fund:
  - Education center.
  - Refurbishment of 4850L & 7400L (partial).
  - O&M of Sanford Laboratory activities.
- Initial allotment ($60M) released, in use.
  - As with this allotment, release of remaining funds is conditional.
- Key staffing underway, including Laboratory Director.
- SDSTA began mine re-entry late July 2007.
  - Dewatering began 21 April 2008.
- Beneficial occupancy of 4850L scheduled end CY08.
- Decoupled from MREFC process, but integrated into DUSEL facility planning.
Education in South Dakota

- No physics PhD-granting institutions in SD.
- $20M of Sanford gift goes toward education center at Sanford Laboratory. Was a primary motivation for his gift.
- SD has very keen interest in supporting education and outreach.
  - SD is an EPSCoR state.
- Is key component of Sanford Laboratory planning, and the evolving DUSEL project plan.
DUSEL Events

• 13 September 2007, Town Meeting in Rapid City, SD
• 2 November 2007, DUSEL Town Meeting, National Academy of Sciences, Washington, D.C.
• 3-4 November 2007, DUSEL Community Workshop, Washington, D.C.
  – 220 participants
• 17 April 2008, Western South Dakota Hydrology Conference, Rapid City, SD
  – Keynote Speaker, John Marburger, OSTP
  – Tour of Homestake by Marburger, Lead, SD
• 20-26 April 2008, DUSEL Homestake Workshop, Lead, SD
  – 350 participants
• 8 September 2008, DUSEL Physics JOG MOU drafted
We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet-unseen violations of time-reversal symmetry, and other key ingredients of the New Standard Model of fundamental interactions. Construction of a Deep Underground Science and Engineering Laboratory is vital to U.S. leadership in core aspects of this initiative.
The three frontiers of research in particle physics, as expressed by the P5 Panel, which form an interlocking framework that addresses fundamental questions about the laws of nature and the cosmos.

• The Particle Physics Project Prioritization Panel (P5) is a sub-panel of the High Energy Physics Advisory Panel (HEPAP).
• Charged in Jan 2008 by NSF and DOE with recommending a 10-year road map for particle physics.
P5 Recommendations

• Report approved by HEPAP at their May 2008 meeting in Washington.

• From Executive Summary:

“\textit{The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL laboratory and a high-intensity neutrino source at Fermilab.}”

“\textit{The panel endorses the importance of a deep underground laboratory to particle physics and urges NSF to make this facility a reality as rapidly as possible. Furthermore the panel recommends that DOE and NSF work together to realize the experimental particle physics program at DUSEL.}”

• Fermilab/DUSEL program recommended by P5 constitutes the primary element of the on-shore U.S. particle physics program during the coming decade.
The configuration of a Mega-Detector at Homestake, that is greater than 1,000 km from a high intensity beam from Fermilab, offers an opportunity for transformational discovery that is unique in the world.
The US Future in Accelerator-Based Particle Physics: The Intensity Frontier

Main Injector:
High Intensity Proton Source for Neutrinos

Recycler:
High intensity beam at low energy for precision experiments

Tevatron Ring

Fermilab

Beam to DUSEL

8 GeV Linac
Discussions on DUSEL with DOE

- NSF/DOE DUSEL Physics Joint Oversight Group (JOG) being developed.
- JOG would oversee those physics experiments jointly implemented by NSF and DOE at DUSEL.
- Roles & responsibilities being based on past models.
  - Among them, successful DOE/NSF JOG oversight of US participation in the Large Hadron Collider (LHC) at CERN.
  - Attending: NSF MPS & PHY, DOE OHEP & ONP.
- Draft MoU describing NSF/DOE cooperation has been agreed to and submitted for approval.
DUSEL Working Timeline

- 16-18 July 08: Internal project review of facility.
- December 08: NSF Project Review of DUSEL.
- December 09: NSF Preliminary Design Review of DUSEL.
  - Project readiness, plan will be assessed at this milestone.
- Spring 10: Presentation of DUSEL package to NSB.
- FY12: Earliest construction funding (MREFC) start, if approved.

Planning with potential partners (DOE, international, etc.) will be integrated into above schedule.
• Planning assumes facility infrastructure construction costs would be borne by NSF.
• Partnerships with DOE & others anticipated for experiments.
  – International, public, private, etc.
• At this early stage, Physics Division uses following rough planning targets:
  – $500M for MREFC, split evenly between facility and experiments.
  – 7-8 year construction period, experiments deployed as they are ready.
  – December 2009 PDR review.
• Infrastructure tailored to meet science goals that fit within initial scope that, in turn, satisfies budget constraints.
An Irreducible Set of Strategic Goals

- Intellectual Frontiers
- Broader Impacts
- Education
- Stewardship
INVESTMENT GOALS

- Major scientific advances that alter the course of physics and other fields
- Seeds of advances in nation’s health (Varmus), wealth (Solow), and defense (Hart-Rudman), also Gathering Storm, ACI, ACA…
- International leadership/cooperation across the intellectual frontiers of science
- Recruitment of exceptional talent into science (education, outreach, and early inspiration)
- Production of highly trained professionals for the nation’s workforce
- Significantly increase diversity in science
A Two-Step Innovation Strategy

• Societal goal: locate, track, target a 5 cm spot on the earth (clearly, many applications)

• Key technology: GPS.

• Required set of independent technologies/ideas: general relativity, quantum mechanics, laser, atomic clock, satellites, communications, microelectronics

• How did that happen? Intellectual ecosystem.

• How do you ensure fecundity of that complex system? Support research whose purpose is to advance the intellectual frontiers.

• Key point is that there are two steps to this strategy, whereas targeted R&D is one step.
A Two Step Innovation Strategy - 2

• In economic terms...(classical concepts are capital, labor, land, etc., all limited resources)

• Knowledge is the only unlimited resource (a nonrival, partially excludable good, Paul Romer, 1990)

• Knowledge is also nonappropriable and indivisible, producing increasing returns.

• The more that becomes known, the more that will be discovered (‘accelerating universe’)

• Production is intrinsically uncertain.

• Therefore, the government must take a lead in cultivating the intellectual ecosystem from which innovation of this type emerges.
A Two-Step Innovation Strategy-3

- Innovation has a potent, two-step, indirect component that has proven to be transformational on a regular basis over time.
- It’s key impacts lie beyond intellectual frontiers and are therefore intrinsically uncertain.
- The universe of ideas/technology is growing at an accelerating rate.
- This aspect of human endeavor globalizes faster than other sectors.
- Future competitiveness depends on innovation power, i.e., the intellectual ecosystem.
- Therefore investment in research at promising frontiers (two-step strategy) should be viewed as part of the innovation strategy.
Fundamental Physics Questions Addressed by DUSEL

• We see only 4 percent of the mass of the universe; of what is the other 96 percent composed?

• Is visible matter stable?

• What are the mass and fundamental properties of the neutrino, and how can these inform our understanding of:
  – The matter/antimatter asymmetry in the universe?
  – The unification of the fundamental forces that govern physical laws?
  – Of what the universe is made; how the elements of the universe were created?
  – The origin and pattern of particle masses?

• What is the spectrum of neutrinos from supernovae and the Big Bang, and what can this tell us about the history and evolution of our universe?
DUSEL Scope Considerations

• Only the most compelling, transformational experiments will be considered for DUSEL.

• This is one factor that will contribute to determining the overall DUSEL scope.

• Cost is another.

• DUSEL solicitation process provides funds to allow the community to estimate costs, including operations, up front.

• Allows NSF approval decisions, and potential scope adjustments, to be made in an informed manner.
DUSEL Status in Project Development Cycle

- DUSEL is following all guidelines in the Large Facilities Manual for project planning, including:
  - Costs & risk-based contingency for all project life cycles (design, construction, O&M)
  - ES&H, including EIS and Integrated Safety Management Systems
  - Management and organization plan
  - Risk analysis and mitigation plan
  - Project Management Controls System
  - PEP

- The Homestake S3 proposal has satisfied the requirements for a CDR (approved by DDLFO).

- MPS Advisory Committee has recommended that DUSEL enter readiness phase, with some qualifying recommendations.
  - See MPSAC report.
South Dakota Science and Technology Authority (SDSTA) owns land (footprint and below) outright and in perpetuity.

Future use dedicated to research and education.
“The Committee commends the Department for its efforts to engage the high energy physics scientific community to provide a bold vision for the future of the Nation's efforts in this area that is both realistic and scientifically compelling, particularly given the difficult budget constraints faced by the field in fiscal year 2008. Given the hefty estimated price tag and elongated timeframe presently envisioned for the ILC, the Committee believes that a balanced effort that addresses opportunities at the energy, luminosity, and cosmic frontiers by leveraging existing physical capital and facilities to the maximum extent possible and by engaging in international scientific cooperation is critical for the future of this field. To this end, the Committee directs the Department to work with the National Science Foundation (NSF) to pursue opportunities to couple facilities at Fermilab with facilities and experiments at the proposed Deep Underground Science and Engineering Laboratory (DUSEL) which may substantially enhance the scientific reach of both projects.”


• DUSEL represents an opportunity for the U.S. to maintain a leadership position at the frontier of astrophysics and nuclear & particle physics, and for the NSF to usher in a unique, world-class, transformational facility in the U.S. for the next generation of scientists.
Working Model for DUSEL Operations

• Operations costs for facility infrastructure would be borne by MPS/PHY.
  – Operations costs for experiments supported by experiment construction partners.

• DUSEL O&M will ramp up as facility takes shape & experiments are deployed.
  – O&M assumed to plateau to ~$50M/yr as lab moves toward full ops mode, ~2017.

• Physics Division has proposed a plan to realize this funding profile, under consideration by MPS.

All models are coarse, used for planning purposes only. Project will produce final numbers that will be peer-reviewed, baselined.