# The Future of U.S. Particle Theory: Report of the DPF Theory Panel

M. Dine (Chair), K. Babu, C. Csaki, S. Dawson,
L. Dixon, S. Gottlieb, J. Harvey, D. Whiteson

Presentation to HEPAP, September 6, 2013 (S. Dawson, BNL)

# Panel Goals

- Charged by DPF executive committee
  - Part of Snowmass process
  - Report submitted to DPF
- Goals:
  - Understand scientific questions and prospects for the next decade
  - Understand challenges involved in sustaining a first class program in the U.S.

# Conclusion in a nutshell

- *"The United States should maintain a vigorous research effort in theoretical particle physics, ranging from perturbative and non-perturbative QCD studies, to collider phenomenology, to model building, cosmology, and research in foundational areas."*

# Input to Panel

- Solicited email contributions (via DPF mailing)
- Significant input from DOE (S. Rolli) and NSF (K. Dienes) ***Thanks!***
- Town meetings at BNL and KITP Snowmass workshops
- At Minneapolis: Two parallel sessions and a plenary session
  - Sessions very well attended
  - Many thoughtful presentations and comments

# Structure of Report

- Successes of U.S. theory effort in the past
- Open questions for U.S. theory effort in the future
  - Physics opportunities
  - Challenges in maintaining world leading theory program in the future
- Recommendations
  - General recommendations for DOE/NSF consideration
  - Suggestions for DOE/NSF Committee of Visitors consideration

# Many Great Successes of Theory

- Theorists straddle intensity, energy, and cosmic frontiers

Examples:

- The Standard Model
  - Quantum field theory
  - Model building
  - Calculational tools: perturbative EW and QCD, Monte Carlos
- CKM phase and CP violation
  - Theory tools: heavy quark systems, effective field theory, lattice gauge theory
- Neutrino masses and oscillations
- AdS/CFT correspondence
  - New tool for study of strongly interacting field theories
- Lots of open questions: Origin of hierarchy, physics of flavor, neutrino masses, dark matter, gravity….

All these ingredients crucial for Higgs discovery

# Many questions for the future

- Why is $M_{Plank} >> M_W$ (Hierarchy problem)?
- Where do the parameters of the SM originate?
- Do the forces unify?
- Why 3 generations with such different masses?
- What accounts for CP violation?
- What is dark matter?
- Where does dark energy come from?
- What caused inflation?
- What is the nature of quantum gravity?

Theory transcends frontiers

# Theory & Experiment

- Some questions will be answered by future experiments
  - Does supersymmetry explain the hierarchy problem?
- Some questions will guide the design of future experiments
  - Can we understand the nature of dark matter?
- Examples of clear prospects for advances in theory detailed in report
  - Lattice gauge theory, phenomenology, effective field theory, perturbative QCD/EW calculations, model building, neutrino physics, flavor physics, astroparticle physics, cosmology, grand unified theories, string theory, formal theory

# Challenges

- NSF theory support reduced by ~10% for FY14
- DOE budget declining and project fraction of budget increasing
  - Theoretical work does not lend itself to "project designation"
- Seemingly modest cuts lead to much larger impacts on post-docs and students

Past formula for supporting broad theory program in the universities and laboratories has been extremely successful, but the model is under stress

# Recommendations, #1

1. It is important to maintain the vitality and international competitiveness of both the laboratory and university based theory programs.
2. The move to extract funds from research for projects should treat theory differently from other areas, as the damage to the program is more severe.
3. A project category for theory, within DOE, could be the existence of theory networks, modeled loosely on such networks in Europe…The network would be geared towards a particular, well-defined need….
4. The breadth of the topics and research areas supported in particle theory should be maintained. The successful formula of funding the best and most interesting research should not be changed…We advocate that programmatic considerations in funding decisions should be kept at a minimal level. It is important not to limit the scope of high-quality theoretical research that is being performed, even if it appears to cross traditional funding agency boundaries.

# Recommendations, #2

5. Both laboratory and university theory groups have historically been vital to the theory effort in the U.S. Both are vulnerable in the likely long term funding environment. HEPAP should examine the question of balancing these resources.
6. A target level of support for researchers in university groups should include ½ postdoc per PI and ½ student…It should include two months of summer salary.
7. Summer salary caps should not be lowered below their current levels.
8. Support for graduate student research should be increased. Ideally, particle theory students would be supported for 3 months during the summer, and for 50% of the terms during the academic year.

# The value of theory

- European Strategy for Particle Physics
  - "Theory is a strong driver of particle physics and provides essential input to experiments…..Europe should support a diverse, vibrant theoretical physics programme, ranging from abstract to applied topics…"
- U.S. experimental physicists (>100 signatures):
  - "We, the undersigned experimental high-energy physicists, believe that a strong experimental high-energy physics program requires a vibrant theoretical physics community in the United States…."
  - http://amanda.uci.edu/~daniel/theory_letter.php

# Conclusion

- Widespread community support for a broad based theory program in the U.S.
- Theory program faces serious challenges in the future, and panel encourages further study of the issues by HEPAP.