Theory @ SLAC: 
A Brief Tour

Just what does a theorist do, anyway???
Basically, we are paid to think.
Basically, we are paid to think.

There really is a SLAC theory think tank.
Main Roles of the SLAC Theory Group:

- **Mentor students & post-docs** *(represent the future of our field!)*
- **Be involved with SLAC’s experimental programs** *(both present and future)*
- **Perform research at the cutting edge of theoretical science**
The cast of characters:

Faculty & Staff:
Stan Brodsky
Lance Dixon
JoAnne Hewett
Shamit Kachru
Michael Peskin
Helen Quinn
Tom Rizzo
Eva Silverstein
Marvin Weinstein

Emeritus:
James Bjorken
Richard Blankenbecler
Sid Drell
Pierre Noyes
Yung-Su Tsai
**Postdoctoral Fellows:**
Stephon Alexander
Charalampos Anastasiou (* to Zurich)
Thomas Becher (* to FNAL)
Richard Hill
Amir Kashani-Poor
Adam Lewandowski
Alex Maloney
Aaron Pierce

**Arriving Next Year:**
Carola Berger
Emmanuel Katz

**Graduate Students:**
Michael Binger (Brodsky)
Wu-Yen Chuang (Peskin)
Michal Fabinger (Silverstein)
Ben Lillie (Hewett)
Xiao Liu (Kachru)
Darius Sadri (Hewett)
Alex Saltman (Silverstein)
Mark Schreiber (Dixon)
The majority of our recent postdoctoral fellows have gone on to faculty positions at major institutions:

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>1990</td>
<td>Vittorio Del Duca &gt; Torino</td>
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<td></td>
<td>Carl Schmidt &gt; Michigan State</td>
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<tr>
<td>1991</td>
<td>Adam Falk &gt; Johns Hopkins</td>
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<td></td>
<td>Patrick Huet</td>
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<td></td>
<td>Roberto Vega &gt; SMU</td>
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<tr>
<td>1992</td>
<td>Alex Kagan &gt; Cincinnati</td>
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<td></td>
<td>Wai-Keung Tang</td>
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<tr>
<td>1993</td>
<td>David Atwood &gt; Iowa State</td>
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<td></td>
<td>Valya Khoze &gt; Durham</td>
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<td></td>
<td>Eric Sather</td>
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<tr>
<td>1994</td>
<td>Scott Thomas &gt; Stanford</td>
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<tr>
<td>1995</td>
<td>Damien Pierce</td>
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<td></td>
<td>Mihir Worah</td>
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<td></td>
<td>James Wells &gt; Michigan</td>
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<tr>
<td>1996</td>
<td>Yuval Grossman &gt; Technion</td>
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<tr>
<td>1997</td>
<td>Nima Arkani-Hamed &gt; Harvard</td>
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<td>1998</td>
<td>John Brodie &gt; (postdoc)</td>
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<td></td>
<td>Hooman Davoudiasl &gt; (postdoc)</td>
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<td></td>
<td>Martin Schmaltz &gt; Boston U</td>
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<tr>
<td>1999</td>
<td>Gundrun Hiller &gt; Munich</td>
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<td></td>
<td>Albion Lawrence &gt; Brandies</td>
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<td></td>
<td>Kirill Melnikov &gt; Hawaii</td>
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<tr>
<td>2000</td>
<td>Simeon Hellerman &gt; (postdoc)</td>
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<tr>
<td>2001</td>
<td>Charalampos Anastasiou &gt; (postdoc)</td>
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<tr>
<td></td>
<td>Thomas Becher &gt; Fermilab</td>
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<td>David E. Kaplan &gt; Johns Hopkins</td>
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<tr>
<td>2004</td>
<td>Emmanuel Katz &gt; Boston U</td>
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</table>
The majority of our recent graduate students have gone on to faculty positions at major institutions:

Matt Strassler > Washington
Jonathan Feng > UC Irvine
Yael Shadmi > Technion
Maxim Perelstein > Cornell
Frank Petriello > (postdoc)
Yue Chen > (postdoc)
Experimental Connections:

- Our theoretical investigations help to define lab’s future experimental projects

- Our investigations relate to important observables for current and future experiments

- We organize formal programs that bring together SLAC experimenters & users & theorists from the broader community

A few examples....
SLAC-R-504
The BaBar Physics Book

PDF

- slac-r-504-Frontmatter-pdf (41.5 KB)
- slac-r-504-TOC-pdf (70.6 KB)

Compressed PostScript

- slac-r-504-Frontmatter-ps (20.8 KB)
  Alternate download methods: old, ancient*
- slac-r-504-TOC-ps (31.4 KB)
  Alternate download methods: old, ancient*

*download methods - technical info

Articles below are listed in the order in which they appear in the printed version. (Use the "find" feature in your browser to find a particular article by title.)

Table of Contents

- Chap01: A CP Violation Primer
- Chap 02: Introduction to Hadronic B Physics
- Chap 03: An Introduction to the BaBar Experiment
- Chap 04: Snapshot of BaBar Software and Analysis Tools
A workshop on semileptonic and radiative B decays

SLAC
Friday-Saturday, December 12-13, 2003

Purpose:

Like in the last two years (2001, 2002), this workshop is intended to bring theorists and BABAR experimentalists together for an appraisal of the theoretical and experimental uncertainties and prospects related to measurements of semileptonic and radiative rare B decays. The intent is to have an informal meeting focusing on physics issues, primarily the interpretation of current and future measurements and theoretical uncertainties. Specifically, we are interested in $b \rightarrow c$, $b \rightarrow u$ and $b \rightarrow s$ measurements, OPE and moments analyses, lattice calculations, form factors, etc. What are the most interesting quantities to measure? what can we measure, and how well? what additional information do we need? can we learn from the various processes?

Talks will be posted to the BaBar internal web. While theoretical talks will be publicly available, the experimental talks (with not-yet preliminary results) will be restricted to BABAR members only.
Second Workshop on the Discovery Potential of an Asymmetric B Factory at $10^{36}$ Luminosity

SLAC
Wednesday-Friday, October 22-24, 2003

Announcement:

With the now rather precise measurement of $\sin^2\theta$ by BABAR and Belle, it is likely that all Standard Model CKM phase accounts for the CP-violating effects measured to date. The inability of the Standard Model CP violation to account for the matter-antimatter asymmetry of the universe tells us, however, that there must be sources of CP violation beyond the Standard Model.

This workshop is aimed at refining our understanding of the capabilities of an asymmetric B Factory at the very high luminosity of $10^{36}$ cm$^{-2}$s$^{-1}$ to uncover effects in rare heavy quark decays that could lead to progress in finding physics beyond the Standard Model. By confronting detailed predictions of Standard Model extensions such as supersymmetry, little Higgs or extra dimensions, with experiments feasible with an integrated data set of 10 to 50 ab$^{-1}$, we will explore the power of a Super B Factory to illuminate the flavor sector of physics beyond the Standard Model and compare this capability with that of experiments based at hadron colliders.
Working groups:

Detector and Physics Simulations:
- Norman Graf (ngraf@slac.stanford.edu)
- Mike Peskin (mpeskin@slac.stanford.edu)

Higgs:
- Tim Barklow (timb@slac.stanford.edu)
- Marcela Carena (carena@fnal.gov)
- Howie Haber (haber@scipp.ucsc.edu)

SUSY:
- Uriel Nauenberg (uriel@cuhep.colorado.edu)
- Jonathan Feng (jlf@uci.edu)
- Frank Paige (paige@bnl.gov)

New Physics at the TeV Scale and Beyond:
- Joanne Hewett (hewett@slac.stanford.edu)
- David Strom (strom@maxwell.uoregon.edu)
- Slawek Tkaczyk (tka@fnal.gov)

Linear Collider Connections to Astrophysics and Cosmology

EDITORIAL COMMITTEE
- Jonathan Feng (co-chair) (jlf@uci.edu)
- Mark Trodden (co-chair) (trodden@physics.syr.edu)
- Marco Battaglia (MBattaglia@lbl.gov)
- Norman Graf (ngraf@slac.stanford.edu)
- Michael Peskin (mpeskin@slac.stanford.edu)
Sample papers with connections (from Spires):

8) RADIATIVE CORRECTIONS TO FIXED TARGET MOLLER SCATTERING INCLUDING HARD BREMSSTRAHLUNG EFFECTS.
e-Print Archive: hep-ph/0210259

2) RADIATIVE CORRECTIONS TO THE AZIMUTHAL ASYMMETRY IN TRANSVERSELY POLARIZED MOLLER SCATTERING.
Published in Phys.Rev.D69:113001,2004
e-Print Archive: hep-ph/0402221

2) COMMENT ON EXTRACTING ALPHA FROM B --- RHO RHO.
Published in Phys.Rev.D69:011502,2004
e-Print Archive: hep-ph/0310242

12) TRANSVERSE POLARIZATION SIGNATURES OF EXTRA DIMENSIONS AT LINEAR COLLIDERS.
Published in JHEP 0302:008,2003
e-Print Archive: hep-ph/0211374

2) HIGH ENERGY PHOTON-PHOTON COLLISIONS AT A LINEAR COLLIDER.
Invited talk at 5th International Workshop on Electron-Electron Interactions at TeV Energies, Santa Cruz, California, 12-14 Dec 2003.
e-Print Archive: hep-ph/0404186

47) SIGNALS FOR NONCOMMUTATIVE INTERACTIONS AT LINEAR COLLIDERS.
Published in Phys.Rev.D64:075012,2001
e-Print Archive: hep-ph/0010354

1) ESTIMATION OF OBLIQUE ELECTROWEAK CORRECTIONS.
Published in Phys.Rev.D46:381-409,1992
QCD @ NNLO

- LHC Physics requires precise theoretical predictions for SM processes
- Few percent predictions require perturbative QCD calculations at 2–loop level (NNLO)
- These calculations are truly daunting. 100's Feynman diagrams per process with 10,000's terms per diagram
- Brute force is not sufficient – need new calculational ideas
- Bern, Dixon, Kosower pioneered systematic calculation of NLO diagrams utilizing string theory relations. Currently extending this to NNLO.
  - Anastasiou developed automated reduction of 10,000's 2–loop integrals to set of ~10 master integrals. Program runs on local PC – loopy.slac.stanford.edu – which does integration by parts 24/7.
  - Anastasiou & Melnikov applied this technique to diagrams with multiparticle phase space.
These techniques allow for the 1st evaluation of a differential cross section to NNLO

\( p\bar{p} \rightarrow Z^{*}\gamma + X \)

With this calculation, LHC data will determine quark & antiquark pdf’s to 1% accuracy

Anastasiou, Dixon, Melnikov, Petriello (2003/4)
Dark Matter and Precision SUSY Measurements

- WMAP measures dark matter density of the universe \( \Omega_{DM} = 0.2 \) with 8% precision. Planck will give 1% precision.
- SUSY provides excellent dark matter candidate, the neutralino LSP – relic density is calculable, but depends on a number of parameters.
- What is the necessary degree of accuracy of SUSY parameter measurements at colliders to compare relic density predictions with Planck (WMAP) measurements?
- Examine slepton coannihilation: \( \tilde{\ell}N \rightarrow \gamma + \ell, \ Z^0 + \ell \)
Slepton mass (and slepton LSP mass difference) must be measured to accuracy of 200 MeV to predict $\Omega$ at the percent level.
Higgsless Electroweak Symmetry Breaking

What good is a Higgs anyway??

• Generates \( W, Z \) Masses
• Generates fermion Masses
• Unitarizes scattering amplitudes \((W_L W_L \rightarrow W_L W_L)\)

Do we really need a Higgs?

And get everything we know right....

Our laboratory: Standard Model in 1 extra warped dimension

⇒ Minimal Particle Content!
Unitarity in Gauge Boson Scattering

- SM without Higgs violates perturbative unitarity in $W_L W_L \rightarrow W_L W_L$ at $\sqrt{s} \sim 1.7$ TeV
- Higgs restores unitarity if $m_H < \text{TeV}$

What do we do without a Higgs????

Exchange KK towers of gauge bosons
Toy Example: Flat space with U(1) gauge field in bulk

Curvature of 5–d wavefunction is related to its 4–d mass

$A^\mu$ cannot be flat with these boundary conditions!

$$A \sim \sum_n a_n \cos(m_n y) + b_n \sin(m_n y)$$

$$\partial_5 A \sim m_n \sum_n (-a_n \sin(m_n y) + b_n \cos(m_n y))$$

BC’s: $A(y=0) = 0 \implies a_n = 0$

$$\partial_5 A(y=\pi R) = 0 \implies \cos(m_n \pi R) = 0$$

$m_n = (n + \frac{1}{2})/R$

The lightest mode is massive!

$A^5$ acts as a Goldstone

$U(1)$ is broken
Realistic Framework:

\[ \text{SU}(2)_L \times \text{SU}(2)_R \times U(1)_{B-L} \text{ in 5-d Warped bulk} \]

Planck brane \rightarrow TeV-brane

BC’s restricted by variation of the action at boundary

\[ \text{SU}(2)_L \times \text{SU}(2)_R \rightarrow \text{SU}(2)_D \]

SU(2) Custodial Symmetry is preserved!

\[ W^\pm, Z \text{ get TeV scale masses} \]
\[ \gamma \text{ left massless!} \]

Parameters:

\[ \kappa = \frac{g_{5R}}{g_{5L}} \text{ (restricted range)} \]
\[ \delta_{L,Y,B,D} \text{ brane kinetic terms} \]
\[ g_{5L} \text{ fixed by } G_F, \quad \lambda = \frac{g_{5B}}{g_{5L}} \text{ fixed by } M_Z \]
What are the preferred gauge KK masses?

Tension Headache:

- **Colliders**
  - Important direct constraints
- **PUV in WW scattering**
  - needs light KK’s
- **Precision EW**
  - needs heavier KK’s

Is there a consistent region of parameter space?
Monte Carlo Exploration of Parameter space

Points which pass all constraints except PUV: (PUV is problematic)

Over 3M points scanned

Prefers light Z’ with small couplings
Perfect for Tevatron RunII & the LC !!

JLH, Lillie, Rizzo
hep-ph/0407059
**D–celeration: a new model of inflation**

- A D–brane in anti–de Sitter space has a local geometry with an extended ‘throat,’ which is infinitely deep in the field theory limit and is smoothed by non–perturbative string effects.
- If a D–0 brane falls down the throat, it takes a long time to reach the bottom.

- From the 4–d viewpoint, this looks like a modification of the kinetic terms of the field dual to the brane position.
- This is an alternative description of the slowly rolling field in inflation.

Kachru, Silverstein
SLAC has an active & dynamic theory group with a broad range of interests!
Don’t forget to register for the 2004 SLAC Summer Institute!