SLAC Theory Group
Program Overview

M. E. Peskin
2003 DOE Program Review

to begin, discuss the personnel and recent development of our group.

budget: $ 2.1 M

90% of this is staff salaries

our primary discretionary expense is the salaries of postdoctoral fellows

Personnel of the SLAC Theory Group

Faculty and Staff

Stanley Brodsky
Lance Dixon
JoAnne Hewett
Shamit Kachru (1/2)
Michael Peskin
Helen Quinn
Tom Rizzo (1/2)
Eva Silverstein (1/2)
Marvin Weinstein

emeritus:

Richard Blankenbecler
James Bjorken
Sidney Drell
Pierre Noyes
Yung-Su Tsai

Postdoctoral Research Associates

Stephon Alexander
Charalampos Anastasiou
Thomas Becher
Simeon Hellerman
Richard Hill
Amir Kashani-Poor
Aaron Pierce

next year:

Adam Lewandowski
Alex Maloney

(past 4 years: 15 offers, 13 accepted)

Long-Term Visitors

Yasaman Farzan
Alfred Goldhaber
Stanislaw Jadach
Vladimir Karmanov
Matthias Klein
Sang-Jin Sin

Graduate Students (Stanford Physics Department)

Allan Adams	Silverstein	
Yue Chen	Peskin	
Wu-Yen Chuang	Peskin	plus 3-4 rotating
Michal Fabinger	Silverstein	1st-year students
Ben Lillie	Brodsky	
Frank Petriello	Hewett	
Darius Sadri	Hewett	
Stewart Siu	Dixon	
Xiao Liu	Kachru	

Our group also hosts the theoretical physics groups from the Stanford Physics Department and from U C Santa Cruz 2 days/week. There is easy and continuing collaboration among our three groups.

Stanford Faculty:

Dimopoulos, Kallosh, Shenker, Susskind, Thomas

U C S C Faculty:

Banks, Dine, Haber

recent changes in the group:

Tsai, Bjorken retirements

- replace each by a postdoctoral fellow

Noyes retirement

- open junior faculty position
  offered to Arkani-Hamed
  renewed search this fall

Blankenbecler retirement

- position goes to the Kavli Institute
  (2 x 1/2 theory positions)

where have our recent postdoctoral fellows gone ?

1990:
Vittorio Del Duca -> Torino
Carl Schmidt -> Michigan State
1991:
Adam Falk -> Johns Hopkins
Patrick Huet
Roberto Vega -> SMU
1992:
Alex Kagan -> Cincinnati
Wai-Keung Tang
1993:
David Atwood -> Iowa State
Valya Khoze -> Durham
Eric Sather
1994:
Scott Thomas -> Stanford
1995:
Damien Pierce
Mihir Worah
Jim Wells -> Michigan
1996:
Yuval Grossman -> Technion
1997:
Nima Arkani-Hamed -> Harvard
1998:
John Brodie -> (postdoc)
Hooman Davoudiasl -> (postdoc)
Martin Schmaltz -> Boston U.
1999:
Gudrun Hiller -> Munich
Albion Lawrence -> Brandies
Kirill Melnikov -> Hawaii
2000:
Simeon Hellerman -> (postdoc)
2001:
David E. Kaplan -> Johns Hopkins

I emphasize the quality and careers of postdoctoral fellows because they play a major part in determining the scientific direction of the group.

We on the faculty consider it one of our important roles to help postdoctoral fellows pursue and solve the problems they are interested in.

Over time, this has produced some of our major work:

1992-93: Falk, Luke, Neubert :

1/m corrections to heavy quark effective theory

1994-97: Feng, Dimopoulos, Thomas, Wells, Pierce, Peskin

collider phenomenology of gauge-mediated SUSY breaking;
supersymmetry spectroscopy and precision measurement

1995-98: Atwood, Soni, Grossman, Worah, Nir

systematics of new physics contributions to CP violation
in B exclusive decays

1998-2000: Arkani-Hamed, Dimopoulos, Dvali, Schmaltz,
Mirabelli, Davoudiasl, Hewett, Rizzo, Perelstein, Peskin

effects of extra dimensions in elementary particle physics,
cosmology, Yukawa couplings, collider signatures

The most recent such wave of activity is in

precision QCD

(see below)

How are we connected to the experimental program ?

We have a continuing day-to-day connection to ongoing experiments.

Our theoretical investigations have anticipated the needs of experiment and provided analyses needed for future projects.

We organize formal programs that support current and future experiments.

(the last of these is easiest to illustrate →)

Linear Collider: this book was organized and edited by P. Grannis and M. Peskin

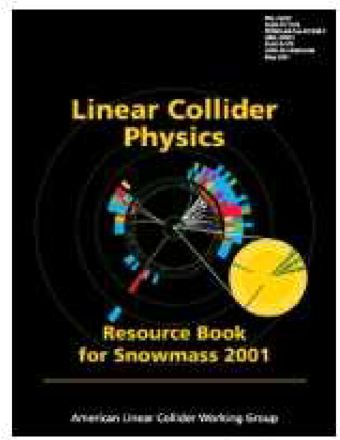
Linear Collider Physics Resource Book for Snowmass 2001

American Linear Collider Working Group

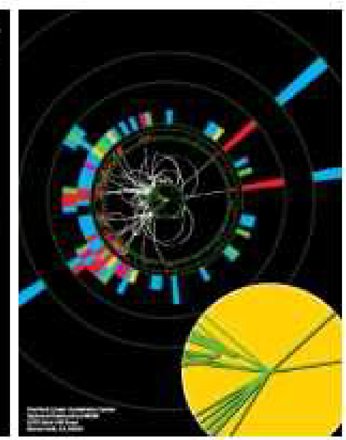
BNL-52627, CLNS 01/1729, FERMILAB-Pub-01/058-E, LBNL-47813, SLAC-R-570, UCRL-ID-143810-DR, LC-REV-2001-074-US

To aid the discussion of linear collider physics at Snowmass 2001, the American Linear Collider Working Group has prepared a resource book containing review articles on the physics issues that will be addressed at the linear collider, and on options for the accelerator and run plan, and on possible detector designs. The book will be distributed in hard copy at Snowmass.

An identical version of the book is made available here. Each item in the table of contents gives the gzipped ps [pdf] file of the corresponding chapter in the book. Extra divider pages and blank pages are included in each file so that, by printing every chapter below, one can assemble the complete book. To download the complete book all at once, click here.



FrontCover.jpg


BackCover.jpg

- **Frontmatter**
  - Title Page, Author List, Table of Contents [pdf]
  - Introduction [pdf]
- **2000 Linear Collider Report**
  - "The Case for a 500 GeV e+e- Linear Collider" [pdf]
- **Sourcebook for Linear Collider Physics**

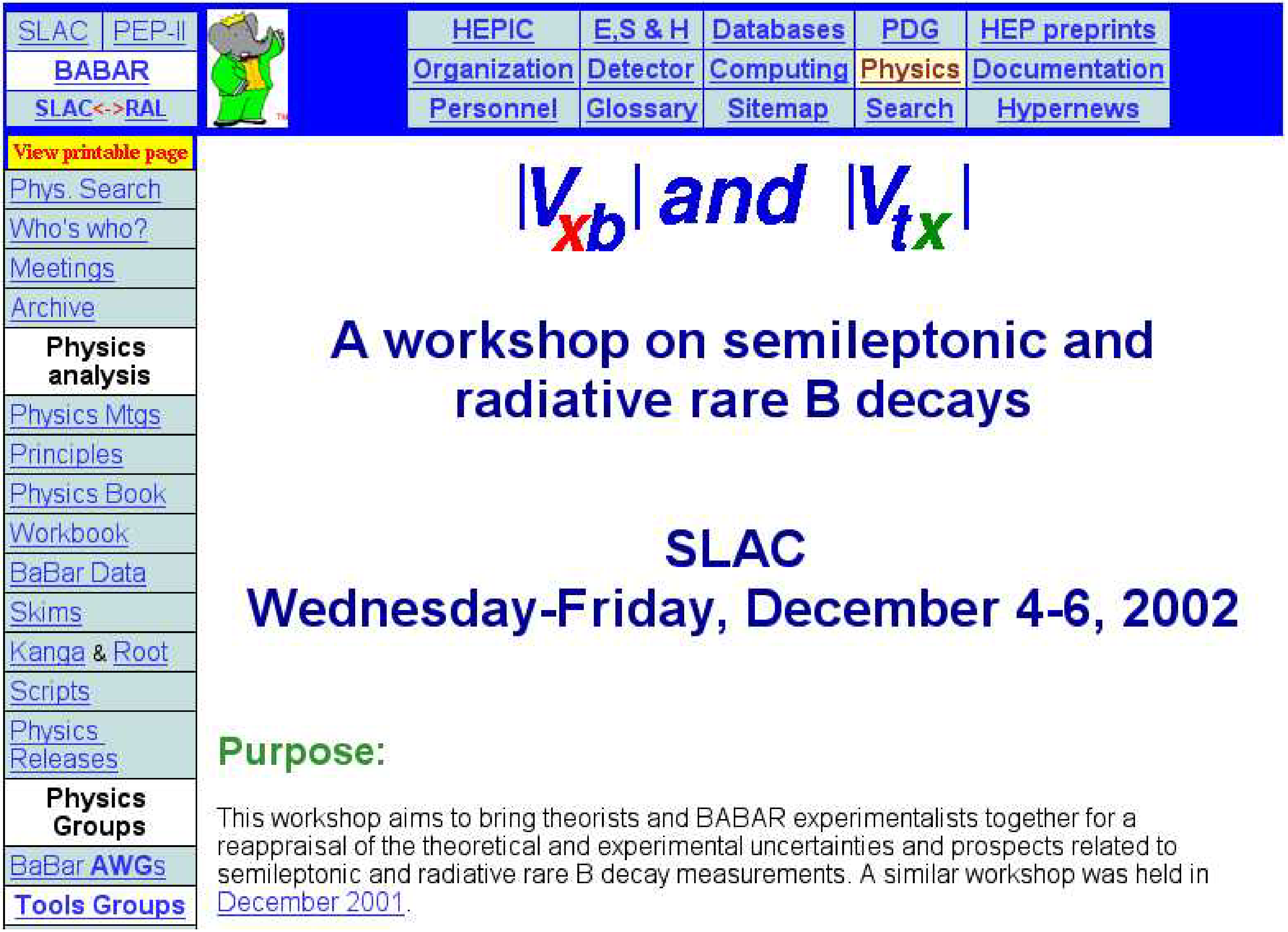
We continue to play an active role in the groundwork for the Linear Collider:

Hewett and Rizzo are active in the current study of LC vs. LHC capabilities

Hewett or Peskin has been a member of the organizing committee for every ALCPWG meeting since Snowmass

one of Peskin's current activities is the event generator pandora, for "do-it-yourself linear collider event generation" in C++, with hadronization by interface to PYTHIA.

BaBar: Thomas Becher and Sven Menke originated this meeting, now in its second year:



JoAnne Hewett and Gudrun Hiller are theory organizers of this meeting:

HEPIC	E,S & H	Databases	PDG	HEP preprints
Organization	Detector	Computing	Physics	Documentation
Personnel	Glossary	Sitemap	Search	Hypernews

Workshop on the Discovery Potential of an Asymmetric B Factory at 10^{36} Luminosity

SLAC
Thursday-Saturday, May 8-10, 2003

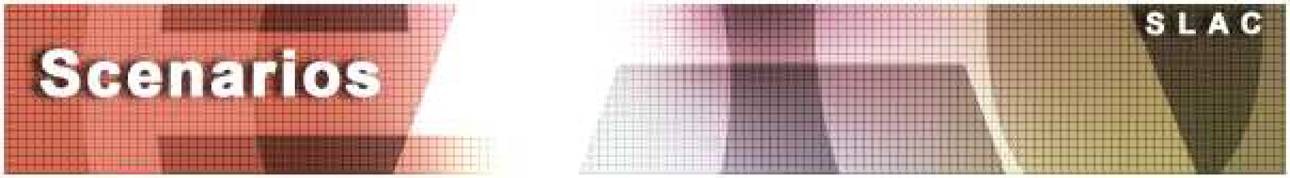
Announcement:

With the now rather precise measurement of sin2beta 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.

Hiller is a 2002 graduate of our postdoctoral program, now junior faculty at the Maximillians Universität, Munich.

While at SLAC, she worked on how to observe penguin amplitudes in exclusive B decays and $B \to l^+ l^- X$.

Lance Dixon is a chair of the "B-side" of the lab's future planning study:



Schedule of Talks & Town meetings

Home

B Day - Thursday March 20, Research Office Building (ROB) Redwood Rooms

Tuesday April 1 - 4:00 - Dave Burke will give a talk titled "An International Linear Collider and What it Might Mean for SLAC" - Orange Room

Friday April 18 - Neutrino Physics Day , Research Office Building (ROB) Redwood Rooms

The following agenda is tentative.

Time	Presentation	Speaker	Institution
9:00 - 9:45	**"The neutrino mass/mixing landscape"**	Boris Kayser	Fermilab
9:45 -10:15	Question & Answer Session		
10:15 -10:45	Break		
10:45 -11:30	**"Present & future accelerator-based neutrino facilities"**	Gary Feldman	Harvard
11:30 - 12:00	Question & Answer Session		

Now I would like to discuss a few of the group's current physics projects.

Our largest single activity at present is the study of methods for high-order diagram calculation in QCD.

It is difficult to underestimate how important this direction is. For the next 10 years--at least--all of our knowledge about the highest energies will come from hadron colliders. The current theory of jets at colliders is correct to ~ 20% accuracy. To do better, we need a full set of NNLO predictions for collider processes.

Similar calculations are need for precision determinations of V_{cb} and other B physics parameters.

For this, it is necessary to compute hundreds of Feynman diagrams per process, with tens of thousands of terms per diagram. Brute strength is not sufficient.

In the early 1990's, Dixon, Bern, and Kosower made a major breakthrough on the related problem of NLO calculation of $2 \rightarrow 3$ processes in QCD.

Using unitarity, helicity, simplifications of the massless limit, and also constraints from supersymmetry and string theory, they showed that the needed loop diagrams could be organized into relatively simple expressions.

In the past few years, Bern and Dixon and Glover and their students, using integration methods by Smirnov and others, have extended these methods to $2 \rightarrow 2$ processes at NNLO.

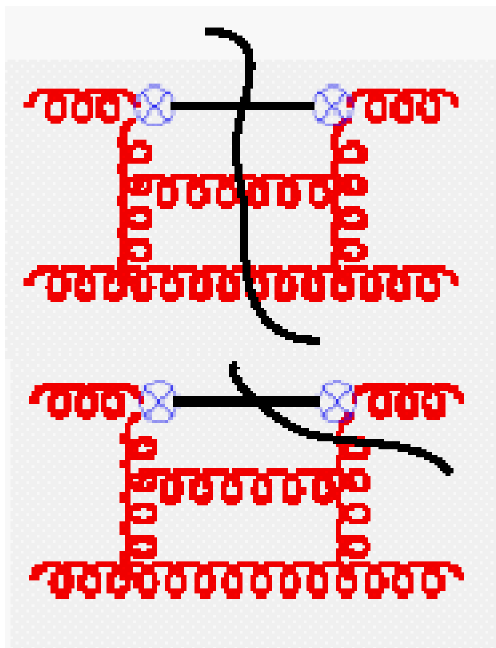
In his thesis with Glover, Anastasiou showed that the needed (tens of thousands of) integrals could be organized and evaluated by systematic integration by parts.

With Dixon and Melnikov, Anastasiou has automated this procedure. We now have a dedicated PC in a closet on the theory floor,

loopy.slac.stanford.edu

that does integration by parts 24 hours a day.

Last year, I described a new trick of Anastasiou and Melnikov: Evaluate unitarity cuts of 3-loop diagrams organized by integration by parts. This puts real and virtual corrections on the same footing.



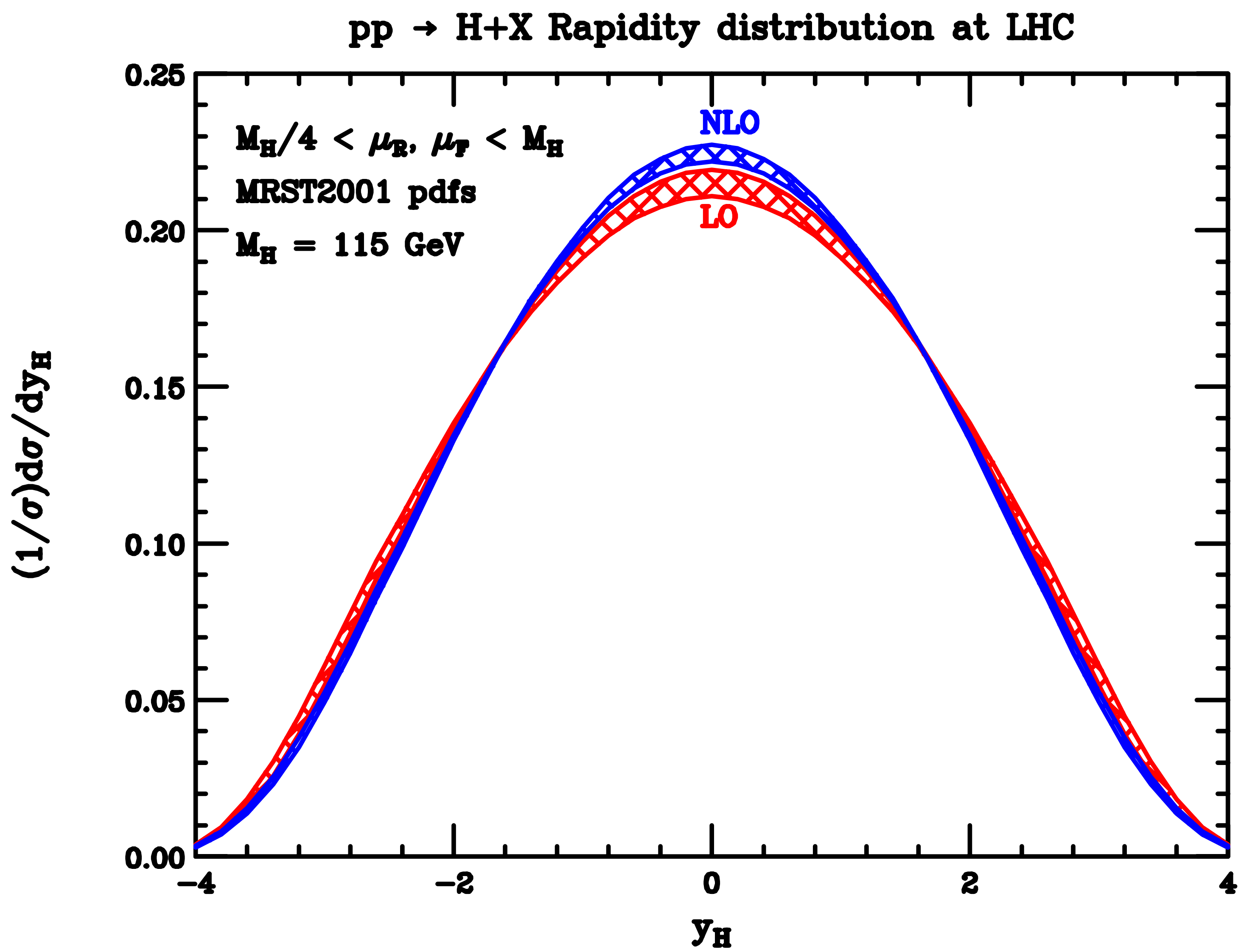
Using this trick, Anastasiou and Melnikov evaluated the cross section for Higgs boson production at the LHC to NNLO (in agreement with Harlander and Kilgore).

This trick opens many possibilities for more detailed calculations. For example, use a Higgs propagator

$$\frac{1}{p_h\,(\,p_1 - u\,p_2\,)}$$

whose cut gives a delta function of Higgs rapidity. Then it possible to compute the Higgs longitudinal momentum distribution to NNLO.

Anastasiou, Dixon, Melnikov, and Petriello are now using this technique to compute the longitudinal momentum distribution in Drell-Yan to NNLO. This will make it possible to use Drell-Yan to extract NNLO parton distributions.



Anastasiou, Dixon, and Melnikov

Some other QCD projects:

Becher, Hill (with Neubert):

use of soft-collinear effective theory to understand factorization in exclusive B decays and the endpoint region in $B \to X \gamma$.

Becher, Melnikov :

combining effective Lagrangians and integration by parts allows one to evaluate one-loop lattice integrals in terms of a small set of master integrals; e.g.,

$$m_{pole} = m_{bare}\left(1 + \alpha_s \left(- \frac{2}{\pi} \log ma + 0.572\,(14) \right) \right)$$

Last summer, Arkani-Hamed, Cohen, Katz, and Nelson introduced a set of models

"Little Higgs"

in which the Higgs is a pseudo-Goldstone boson. These models give a new approach to the origin of electroweak symmetry breaking.

Several members of our group are investigating the experimental implications of this mechanism.

In Little Higgs models, the quadratic divergences in the Higgs mass term are cancelled by diagrams containing additional W and Z bosons and top quarks.

Natural cancellation requires that these new particles have mass at most ~ 2 TeV.

However, such relatively light W, Z, T can potentially ruin the agreement of theory and experiment for precision electroweak observables. What are the bounds ?

Hewett, Petriello, and Rizzo made a detailed study of this question. (There is a similar study by Csaki, Terning, et al.)

They concluded:

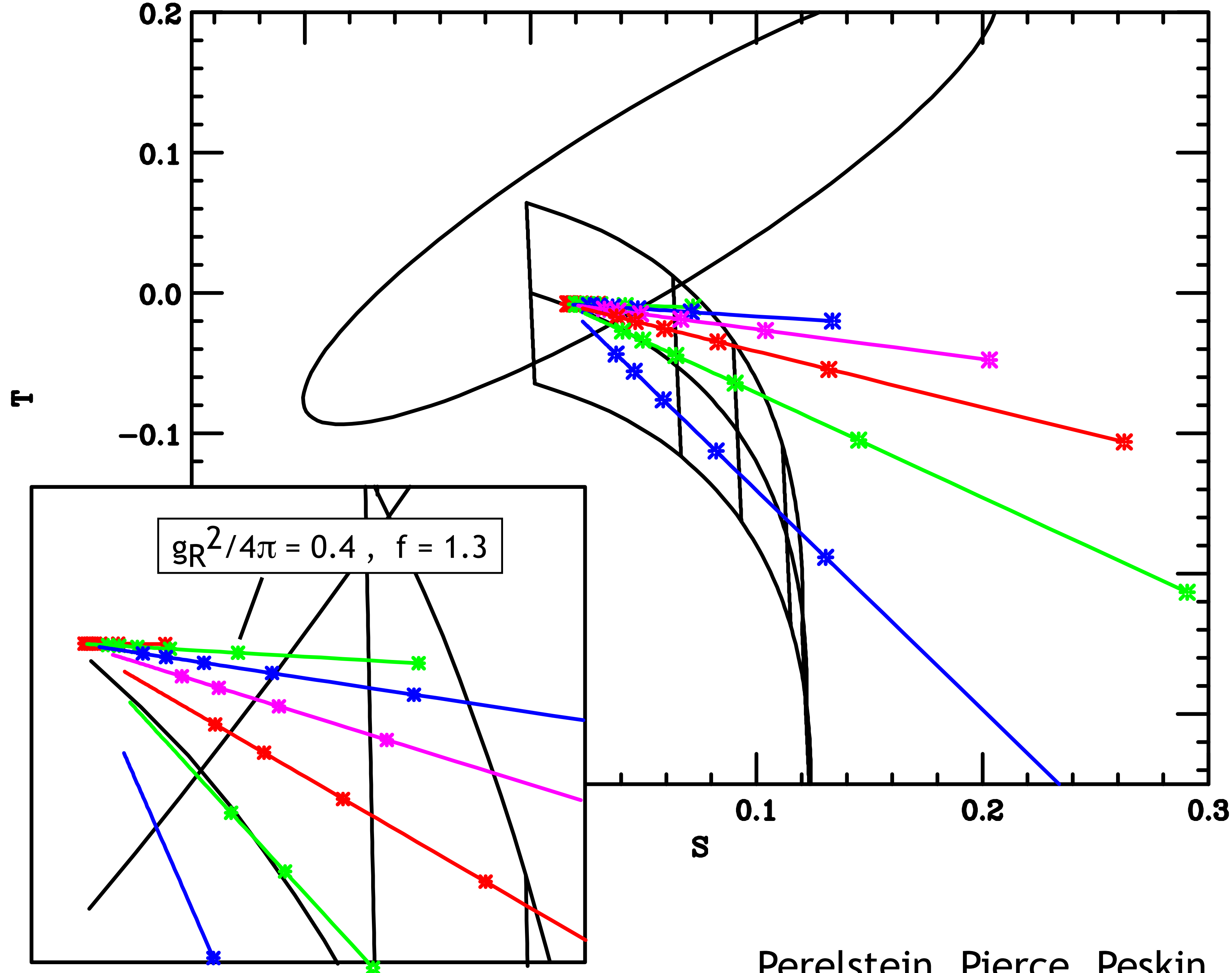
Little Higgs models typically contain a second U(1) gauge boson with TeV mass. This object is very dangerous, with respect to both precision electroweak and direct Z' bounds.

The geometry of Little Higgs models can lead to custodial SU(2) violation. This is very dangerous with respect to precision electroweak bounds.

Loop diagrams containing the heavy T, while potentially dangerous, are unimportant except in special regions.

With this insight, Arkani-Hamed, Wacker, and Petriello have suggested strategies for building Little Higgs models with W and T masses at the natural values.

e.g., using SU(5)/SO(5) but gauging only SU(2)XU(1)XSU(2):



Perelstein, Pierce, Peskin

We are interested in the question, if these models are true, how can we prove them experimentally ?

Cancellation of the divergences and calculation of the negative Higgs $(mass)^2$ from top loops requires the following relation of the t_L and T_L Yukawa couplings to t_R.

$$m_T / f = (\lambda_t^2 + \lambda_T^2) / \lambda_T$$

This is a very interesting relation, because all four quantities can potentially be measured. The hard part is measuring λ_T for a heavy T: $m_T > 2$ TeV. Pierce, Perelstein, and Peskin are looking at:

LHC: width of T, $b\, q \rightarrow T\, q$ cross section

LC: $e^+e^- \rightarrow \nu\, \bar{\nu}\, b\, \bar{b}$, w T in t-channel

Finally, string theory is a major activity in the SLAC Theory Group. Kachru and Silverstein, with students, postdocs, and colleagues on campus, have a leading program in this area.

Why do we have string theory at a DOE laboratory ?

String theory is one of the most intellectually active areas of high energy theory.

String theory brings in new concepts that can be tested experimentally. This is why the phenomenological study of extra dimensions originated at SLAC/Stanford.

To explain the cosmological constant, quark and lepton generations and Yukawa couplings, we must go beyond quantum field theory. At present, string theory is the only way to get there.

One current direction being explored by Kachru is the study of string compactification with background fluxes.

High-dimensional supergravities, and string theory, contain higher-spin gauge fields, e.g.,

$$B_{\mu\nu} \qquad D_{\mu\nu\lambda\sigma}$$

with field strengths dB, dD, etc. These fields have sources on D-branes of the appropriate dimension, and they can also exist as pure fluxes wrapping around compact dimensions.

By adding branes and turning on fluxes, Kachru (with Schultz, Tripathy, Trivedi) finds new string compactifications with lower supersymmetry (N=1 or 0) and less vacuum degeneracy than more standard Calabi-Yau compactifications.

A beautiful aspect of these theories is that the superpotential (origin of Yukawa couplings) is derived geometrically. For example, in one of these models:

$$\hat{W}_{\mathrm{IIB}} = \int \hat{G}_3 \wedge \hat{\Omega}_{\mathrm{IIB}}$$

where $\hat{G}_3$ is a 3-flux produced by:

Term in $\hat{G}_3$	Domain Wall
$F_{5(yx)}$	D3-brane transverse to x and y
$k_{(x)} \wedge F_{3(y)}$	D5-brane wrapped on x, transverse to y
$k_{(y)} \wedge F_{3(x)}$	D5-brane wrapped on y, transverse to x
$(\det_{xy}\hat{j})\eta^x \wedge \eta^y \wedge F_1$	D7-brane wrapped on x and y
$\hat{\mathcal{H}}_3$	NS5-brane wrapped on x and y
$\hat{j}_{xx}\eta^x \wedge d\hat{j}_{(x)}$	KK5-brane transverse to x
$\hat{j}_{yy}\eta^y \wedge d\hat{j}_{(y)}$	KK5-brane transverse to y

Using this construction, Kachru, Kallosh, Linde and Trivedi have constructed models on a 4-d anti-de Sitter background space-time. Then, adding D-branes, they can titrate the cosmological constant through 0 to positive values.

These are the first explicit string solutions with de Sitter ($\Lambda > 0$) background space-time.

Thus, in this talk, I have illustrated a number of activities of the SLAC Theory Group

introducing new methods and concepts for particle physics

assisting the present and future HEP experimental program

educating the next generation of high-energy theorists