High Energy Theory

BNL
April 2004
S. Dawson
Group Members

Senior staff
Creutz, Dawson, Marciano, Paige, Soni, Trueman
Pisarski
• Sabbatical at Niels Bohr Institute, Copenhagen; 9/04-9/05

Associate physicist
Kilgore

Post-docs
Berruto (lattice), Chen (Neutrinos, SO(10))
Kulesza (pQCD) (to Karlsruhe, 10/03)
Krupovnickas (Isajet/SUSY) (10/04)

CRISIS: LACK OF POST-DOCS!!!!

No Summer program/few visitors
Large Theoretical Effort in Physics department

- Physics Department
  - High Energy Theory
  - Nuclear Theory
  - Condensed Matter
  - RIKEN/BNL RC

Riken focuses on lattice, spin, RHIC physics
Riken has no permanent staff at BNL

Roughly 40 theorists in department
Largest theory effort in US!
(Some) Group Activities*

Closely linked to US experimental program: RHIC, Tevatron, LHC, B Factories, VLBL ν, LC, RSVP

Collider physics; connection to US ATLAS See talk by Paige [Dawson, Kilgore, Paige]

- Kilgore (hep-ph/0403128) Subtraction Terms for Hadronic Production Processes at Next-To-Next-to-Leading Order
- Kilgore (hep-ph/0304035) Higgs Boson Production in Bottom Quark Fusion at Next-to-Next-to Leading Order
- Dawson, Dicus, Kao, Malhotra (hep-ph/0402172) Discovering the Higgs Bosons of Minimal Supersymmetry with Muons and a Bottom Quark
- Dawson, Jackson, Reina, Wackeroth (hep-ph/0311067) Exclusive Higgs Boson Production with Bottom Quarks at Hadron Colliders
- Paige, Protopescu, Baer, Tata (hep-ph/0312045) ISAJET 7.69: A Monte Carlo Event Generator for pp, anti-p p and e⁺e⁻ Reactions

*Not complete list of papers
(More) Group Activities

- **SUSY studies** [Chen, Paige]
  - Paige (hep-ph/0307342) *SUSY Signatures in ATLAS at LHC*
  - Chen, Mahanthappa (hep-ph/0305088) *Fermion Masses and Mixing and CP Violation in SO(10) Models with Family Symmetry*

- **Electroweak precision physics** [Marciano]
  - Marciano (hep-ph/0402299) *Precise Determination of $|V_{us}|$ from Lattice Calculations of Pseudoscalar Decay Constants*

- **Neutrino studies** [Chen, Marciano] See talk by Marciano
  - Chen and Mahanthappa (hep-ph/0311034) *An Overview of Neutrino Masses and Mixing in SO(10) Models*
  - Marciano…. (hep-ex/0306053) *Megaton Modular Multi-Purpose Neutrino Detector for a Program of Physics in the Homestake DUSEL*

**Broad based, diverse program**
(Still More) Group Activities

- **Lattice gauge theory** [Berruto, Creutz, Soni] See talk by Creutz
  
- **Field theory** [Creutz, Pisarski, Trueman]
  
  - Creutz (hep-ph/0312225) *On the Up Quark Mass*
  
  - Creutz (hep-lat/0312018) *Spontaneous Violation of CP Symmetry in the Strong Interactions*
  
- **Spin studies: What is the RHIC polarization?** [Trueman]
  
  - Trueman (hep-ph/0305085) *Proton Carbon CNI Polarimetry and the Spin Dependence of the Pomeron*
  
- **B Physics** [Soni]
  
  - Atwood and Soni (hep-ph/0312100) *Pathways to a Clean Gamma: From B to Super B Factories*
  
  - Atwood and Soni (hep-ph/0304085) *Role of Charm Factory in Extracting CKM Phase Information via B→DK*
Rob Pisarski on sabbatical:

- Rob’s talks in Europe on the RHIC program:
  - Chasing the Unicorn: RHIC and the QGP (11/3/04, 18/2/04, 9/2/04)
  - All the World’s (almost) a Critical Point (1/3/04)
  - Deconfining Transition as a Matrix Model of Renormalized Polyakov Loops (12/2/04, 10/2/04, 5/2/04, 28/11/03, 24/11/03)
  - Highlights of Quark Matter 2004 (2/2/04)
  - Fluctuations from Polyakov Loops, and other Means (15/12/03; 19/12/03)

_Persuasive Advocate for RHIC physics!

“The unicorn is like the quark-gluon plasma: A mythical beast and hard to know when you’ve found it”
Lattice Effort
Spans HET/NT/RBRC

• Current research based on RIKEN QCDSP machine (600 Gflops peak)
• Next generation: RBRC-QCDOC machine (10 Tflops)
• Physics topics:
  – Hadronic contribution to \( (g-2)_\mu \) (Blum)
  – Improvements to \( \varepsilon'/\varepsilon \) (smaller lattice spacing with charm included; dynamical domain wall fermions)
  – B matrix elements (needed for \( B_s \) and \( B_d \) mixing)
  – Coming soon: new \( B_K \) with domain wall fermions
  – \( g_V, g_A \) on the lattice
Lattice and CKM parameters

• Marciano (hep-ph/0402299)
  – Precise Determination of $|V_{us}|$ from Lattice Calculations of Pseudoscalar Decay Constants
• Use new lattice results for $f_K/f_\pi = 1.201 (8)(15)$
  – Error in ratio is smaller than individual errors

\[
\frac{\Gamma(K \rightarrow \mu e \nu)_{\text{true}}}{\Gamma(\pi \rightarrow \mu e \nu)_{\text{true}}} = \frac{|V_{us}|^2 f_K^2 m_K \left(1 - \frac{m_\mu^2}{m_K^2}\right)^2}{|V_{ud}|^2 f_\pi^2 m_\pi \left(1 - \frac{m_\mu^2}{m_\pi^2}\right)^2 \times (0.9930(35))}
\]

• Marciano:

\[|V_{us}| = 0.2236(30)\]

• \textit{cf} PDG $|V_{us}| = 0.2196 (26)$

\[|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9969 (15)\]

• PDG value is $2\sigma$ from 1

• New result has better agreement with 3 generation CKM unitarity
Measuring CKM Angles at B Factories

- Want to measure $\alpha$, $\beta$, $\gamma$ separately and verify $\alpha + \beta + \gamma = \pi$
- Measure $\gamma$ from direct CP violation:
  
  \[ B^\pm \rightarrow K^\pm D^0 \]
  
  \[ B^\pm \rightarrow K^{\mp} \bar{D}^0 \]

- Followed by decays to common final states, eg
  
  \[ D^0 \rightarrow K^+\pi^-, D^0 \rightarrow K_s\omega \]

- Extract $\gamma$ from interference

3σ at current B factories

3σ at super B factories (50X current)

Black curve is combination of many decays

Atwood and Soni, (hep-ph/0312100): Pathways to a clean $\gamma$: From B to Super B Factories
Teaching, etc.

- Marciano, Adjunct at Yale, *Quantum Field Theory, Spring, 2002*
- Creutz, Adjunct at Stony Brook, *Lattice Gauge Theory, Spring, 2001*
- Dawson, Adjunct at Stony Brook, *Electroweak Symmetry Breaking, Fall, 2001; Particle Physics, Fall, 2003.*
- Summer Schools: SLAC Summer School 04, Trieste 03 (Marciano), Maria Laach 04 (Dawson), CTEQ 04 (Kilgore)

Humboldt Senior Researcher: Marciano, Pisarski
Graduate Students

- Bryan Field (Stony Brook); Dawson
  - Graduates 5/05?

\[ gg \rightarrow gh \]

- Scalar and Pseudoscalar Higgs plus one Jet Production at the LHC and Tevatron,
  Field, Dawson, Smith, hep-ph/0311199

- $b$ quarks important in MSSM for $\tan \beta > 7$
- Affects use of large $m_t$ limit for NLO QCD corrections

- We don’t adequately support students….every $ is a struggle
- Please comment: Are students a good thing for us?
Graduate Students

- Jack Laiho (Princeton); Soni
  - Graduates 8/04; job at FNAL
  - Supported 2003/2004 by LDRD funds
  - Lattice Extraction of $K \rightarrow \pi \pi$ Amplitudes to NLO in Quenched and in full Chiral Perturbation Theory, Laiho and Soni, hep-ph/0306035
  - Framework for lattice calculation of $\varepsilon'/\varepsilon$ to next-to-leading order in chiral perturbation theory
  - Previous studies are LO in chiral PT
  - Mix of lattice/analytic calculations

- Hatta (Tokyo); Pisarski
  - Graduated 2/04; job at BNL with RIKEN
  - Deconfining Phase Transition as a Matrix Model of Renormalized Polyakov Loops, Dumitru, Hatta, Lenaghan, Pisarski, hep-th/0311223
  - Phase transitions and finite temperature QCD
Planning for the US HEP Future

• Neutrino physics
  – VLBLv APS study working group leader (Marciano)
  – BNL working group (Chen, Marciano)
  – Underground Laboratory Steering Committee (Marciano)

• ATLAS
  – SUSY group leader (Paige)

• Linear Collider Studies
  – Working group leaders (Dawson, Marciano, Paige)
  – USLC Steering Committee (Dawson)

• B Physics working groups
  – (Soni)

• LHC/LC Complementarity
  – (Paige, Dawson)

• Spin Physics at RHIC
  – (Trueman)
Meetings organized by HET

Group Members

SciDac Lattice
Gauge Theory All
Hands Meeting

Lattice QCD at Finite
Temperature and Density

Neutrino Superbeam,
Detectors, and Proton
Decay (APS Study)

Proton Decay, Neutrino
Oscillation Detector at a
U.S. Underground
Laboratory (UCLA)

BNL Summer School on
QCD Spin Physics

New Challenges for Lattice
Gauge Theory, Santa
Barbara, Jan-Mar, ’05

Support from BSA, RIKEN
Public Service

- **Editorial work**
  - *PRD* - Dawson, Pisarski, Paige
  - *JHEP* - Marciano
  - *Computers in Science & Eng.* - Creutz

- **Lattice QCD SciDAC-EC**
  - Creutz

- **APS Service**
  - APS Council, DPF chair - Dawson
  - NYSS-EC - Kilgore

- **DOE Service**
  - P5, Facilities - Marciano
  - HEPAP Communications - Dawson
The future:

• Most critical items:
  – Post-docs, post-docs, post-docs
  – Graduate students
  – Summer program

• Plan for changes in lattice effort
  – Connections with NT, RBRC
  – Scientific leadership

• Strong theory component of ATLAS analysis center
  – Workshops, seminars, Monte Carlo effort
  – Make BNL a center for LHC physics

• Emerging BNL interest in LSST
  – Can theory group enhance this effort?