High Energy Theory @ BNL
A Direct Connection to Experiment

S. Dawson
May, 2010
Staff

• Permanent
  – Creutz, Dawson, Kilgore, Marciano, Paige, Soni (group leader)
  – Trueman (emeritus)
• Junior Staff
  – Davoudiasl, Izubuchi (50% RIKEN funding)
• Post-docs
  – Kile, Lee (partial PECASE funding), McElmurry, Sturm, Van de Water (partial Goldhaber funding), Witzel (100% Scidac funding)
• Students
  – Almeida(SB), Jaiswal(SB), Misumi (Kyoto, 100% JSPS funding)

Supported by DOE

• DOE ’08 Theory Review panel concerned with long term future of group
• We have hired Izubuchi, Van de Water since then, increased # of post-docs
• Important to keep young physicists in group
Staff

• Phenomenology
  – Davoudiasl, Dawson, Kile, Kilgore, Lee, Marciano, McElmurry, Paige, Soni, Sturm

• Lattice
  – Creutz, Izubuchi, Soni, Van de Water, Witzel (50% software)

• Creutz: Sabbatical leave, Mainz, 2009-2010

• Oct. 2010: Kile, Sturm leave; 1 new post-doc hired
  Students reduced by 1
Theory ⇔ Experiment

• Tevatron & LHC
  – Monte Carlo tools for discovery (Paige)
  – ATLAS jet calibration (Paige)
  – Precision predictions from QCD (Dawson, Kilgore, McElmurrey, Sturm)
  – Beyond the Standard Model physics
    • Warped Extra Dimensions (Davoudiasl, Soni)
    • MSSM (Dawson, Lee)

• Formal Lattice Gauge Theory Issues
  – (Creutz, Izubuchi)

• Weak interaction physics
  – Lattice predictions (Izubuchi, Soni, Van de Water, Witzel)
  – A probe of BSM physics (Soni)

• Precision low energy physics
  – (Marciano)

Leadership in extracting physics from experiment
LHC Physics

• Connections to experiment
  – F. Paige a member of ATLAS collaboration
    • Leadership roles in ATLAS SUSY and jet calibration studies
    • Intellectual effort full time on ATLAS physics for over a decade
  – Regular HET Theory/ATLAS joint seminars
  – Brookhaven Forum (Nov, 2008; May, 2010)
    • BSM physics at Tevatron/LHC; cosmology
  – LHC@BNL 1 day meetings
    • March 16, 2009 (Vector bosons plus jets at the LHC)
    • June 19, 2009 (Top quarks at the LHC)
    • Feb. 8, 2010 (First Physics at the LHC)
    • July 12, 2010 (QCD at the LHC)
  – Loopfest meetings (May, 2009; June, 2010)
    • QCD calculations for the LHC
  – W/Z’s at RHIC, Tevatron, LHC Workshop (June, 2010)
    • RIKEN workshop

Lively physics environment!
Theory ⇔ Experiment

• Low energy precision measurements
  – g-2, mu2e, EDM (Marciano)

• Neutrino physics
  – Long baseline neutrino experiments (Marciano)
    • Central role in originating and supporting LBNE physics
  – Neutrinos detectors as probes of dark matter (Kile)

Leadership in defining future US experimental program
Physics Highlight: Jet Calibration at ATLAS

- Collaboration between Paige and BNL ATLAS group
- Understanding jet energy scale critical for top physics, new physics searches
- Want jet energy scale to 1 TeV
- Monte Carlo predictions.....to be compared with data
- Uses information from tracking and calorimeter

Details in talk by M. Begel
Theory Highlight: CP Violation in B System

• Soni et al [arXiv: 1002.0595]

• 4th generation has new phases
  – Enhancement of O(100) relative to SM possible
    \[ A_{SL}^S = \frac{\Gamma(\bar{B}_s \rightarrow l^+ X) - \Gamma(B_s \rightarrow l^- X)}{\Gamma(\bar{B}_s \rightarrow l^+ X) - \Gamma(B_s \rightarrow l^- X)} \]
  – \( S_{\psi\phi} (SM) = -0.04, A_{SL} (SM) \sim 10^{-5} \)

Closely related to recent D0 measurement of asymmetry in B decays to same sign muons
Theory Highlight: Precision Predictions for the LHC

• 2-loop Electroweak corrections to Higgs production \((gg\rightarrow H)\)

• K factor is ratio to LO prediction

• Bands are variation with unphysical renormalization scale

• Corrections change FNAL Higgs bound!

Sturm, arXiv:1001.3360, 0809.3667
Theory Highlights, FY09-10

• Warped extra dimension signatures in 1 fb\(^{-1}\) at the LHC
  – Davoudiasl, Soni, arXiv:0908.1131

• Dark matter signatures in neutrino interactions for MeV Dark matter
  – Kile & Soni, arXiv: 0908.3892

• NLO EW calculation of Higgs + b production (discovery channel for MSSM Higgs)
Lattice Gauge Theory at BNL

• HET group
• RIKEN BNL Research Center
  – No permanent staff
  – Completely funded by Japan
  – Significant number of lattice gauge post-docs/fellows
• F. Karsch group
  – Supported by Nuclear Physics DOE
  – Focused on finite temperature QCD
• Groups come together in RIKEN BNL Collaboration (RBC)
  – Regular meetings at BNL & Columbia
  – Significant hardware resources at BNL

US-QCD Meeting at BNL April, 2010
Lattice Phenomenology

• Much data from experiments aimed at pinning down CKM matrix elements
  – Lattice calculations necessary to interpret many of the results: Experiment=CKM x Lattice
  – Need to include effects of combining quarks into hadrons
  – Program of computing decay constants and form factors in lattice QCD
  – Software leadership

Izubuchi, Soni, Van de Water, Witzel
Lattice Highlight

- Two independent groups with BNL physicists are calculating $B_K$ with different lattice formulations.
- Aubin, Laiho, van de Water obtained first 3-flavor lattice determination at two lattice spacings with 4% error.
- RBC/UKQCD (Lattice 2009) : Three flavor lattice calculation with 4% error.
Lattice Gauge Theory Highlight

• Experiments measure $f_+(0) \times |V_{us}| = 0.2166(5)$ to $0.2\%$ accuracy
  – RBC/UKQCD lattice collaboration calculated $K \to \pi \nu$ form factor including effects of $u$, $d$, $s$ sea quarks

• This leads to current best determination of CKM matrix element $|V_{us}|$ with error of $0.6\%$

RBC Collaboration, arXiv:0912.0214, 0911.3127
Quark Masses from the lattice

Particle Data Group 2008

Up Quark mass [MeV]
RBC09 Preliminary: 2.80 (36)_{Stat.} (21)_{FV,ChPT}

JAMIN 06 THEO 0.1
NARISON 06 THFD 1.1
AUBIN 04A LATT 0.8
11.7
(Confidence Level = 0.009)

Down Quark mass [MeV]
RBC09 Preliminary: 4.85 (57)_{Stat.} (11)_{FV,ChPT}

JAMIN 06 THEO 0.1
NARISON 06 THFD 0.2
AUBIN 04A LATT 1.3
6.8
(Confidence Level = 0.088)
Awards/Community Service

• **M. Creutz**
  – Humboldt Research Award, 2009
  – US Lattice Gauge Executive Committee.
  – Adjunct Professor, SUNY, Stony Brook.
  – Co-PI on SciDAC proposal for lattice gauge infrastructure

• **S. Dawson**
  – AAAS Physics Section member at Large; Fermilab PAC member; Sakurai Prize Committee member; US ILC Steering Committee member;
  – Adjunct Professor, SUNY, Stony Brook

• **H. Davoudiasl**
  – PECASE award

• **W. Marciano**
  – International Advisory Committees: KAON09, PAVI09,CKM2010, Tau2010, PSI2010
  – KVI Lab Review Committee Jan 2009
  – JLAB PAC 2008-2012
Awards/Community Service

• H. Lee
  – Webmaster, member publicity and editorial committee of Association of Korean Physicists in America (AKPA)

• W. Kilgore
  – Working Group Leader, "W mass measurement", WHEPP XI, Ahmedabad, India

• A. Soni
  – Working group Convenor: Top Quark Physics Session, DPF2009

• R. Van de Water
  – Organizing committee: Lattice QCD Meets Experiment 2010" at Fermilab, April 26-27, 2010

• L. Almeida
  – SBU Distinguished Doctoral Thesis Award
Our Post-Docs Succeed

- S. Gopalakrishna (06-09) Chennai
- C. Jackson (05-08) Texas Arlington
- M.C. Chen (03-05) California, Irvine
- T. Blum (95-08) U. Conn.
- E. Scholtz (06-08), Regensburg
- C. Dawson (98-07) Virginia
- C. Originos (00-03), William & Mary
- S. Prelovsek (01-02) Ljubljana
- S. Heinemeyer (00-02) Santander
- D. Boer (98-01) Amsterdam
- W. Harlander (99-01) Wuppertal
- A. Czarnecki (98-00) Alberta
- M. Wingate (97-00) Cambridge
- K. Kiers (96-98) Taylor
- M. Tytgat (95-98) Brussels
- L. Reina (94-97) Florida State
- S. Willenbrock (88-93) Illinois
- S. Aoki (87-89), Tsukuba
- ...
Conclusions

• Active efforts in low energy precision measurements, neutrino physics, Tevatron and LHC physics, B physics
  – Direct connections to experiment
  – Group has important role in defining US experimental program
• Lattice efforts connect theory to experiment
  – Strong efforts in weak matrix elements and algorithm development
• Young group members (students, post-docs, junior staff) make vital contributions
• Budget issues make maintaining staff size difficult

BNL theorists play very unique role....different from university theorists
External Talks by Group Members
(1/09-present)
M. Creutz

- 10 March 2009, Monte Carlo methods and simulating quarks, iUlam Centennial Conference, Florida State
- 27 March 2009, Anomalies and chiral symmetry in QCD, Theory seminar, Univ. of Calif. San Diego.
- 7 April 2009, From boats to antimatter, presentation to high school students at the Nassau Science Explorations.
- 3 September 2009, Four dimensional graphene and chiral fermions, keynote speaker at the "ICREA Workshop on quantum gauge theories and ultracold atoms," Mon San Benet, Spain.
- 7 September 2009, Anomalies and chiral symmetry in QCD, invited talk at the "QCD-TNT International workshop on QCD Green's functions, phenomenology, and confinement," Trento, Italy
- 15 October 2009, Lattices and non-perturbative field theory, invited talk at the joint APS-DNP and Japan Physical Society meeting, Waikoloa, Hawaii.
- 12 November 2009, Anomalies and discrete chiral symmetries, theory seminar, Frankfurt University
- 24 November 2009, Anomalies and discrete chiral symmetries, invited talk at "FAIR lattice QCD days," GSI Darmstadt, Germany.
- 11 January 2010, Four dimensional graphene and chiral fermions, theory seminar, DESY Zeuthen
- 13 January 2010, Anomalies and chiral symmetry in QCD, theory seminar, Technical University of Munich
- 19 January 2010, Quarks gluons, and lattices, physics colloquium, University of Mainz, Germany.
- 25 January 2010, Chiral symmetry versus the lattice, nuclear physics seminar, University of Mainz
- 2 February 2010, Anomalies and discrete chiral symmetries, theory seminar, University of Mainz
- 29 April 2010, Four-dimensional graphene and chiral fermions, lecture to graduate students at the University of Graz, Austria.
- 30 April 2010, Anomalies, gauge field topology, and the lattice," lecture to graduate students at the University of Graz, Austria.
- 4 May 2010, Anomalies, gauge field topology, and the lattice invited talk at "Origins of Mass," at the CPI-Origins Institute, University of Southern Denmark, Odense, Denmark.
• H. Davoudiasl

• May 10-12, 2010, Clean Signals of Little Randall-Sundrum Models at the LHC, Pheno10, University of Wisconsin, Madison
• June 5-10, 2009, Signals of Warped Top-Condensation in B-Decays, SUSY 2009, Northeastern University, Boston, MA
• June 2-4, 2009, Echoes from a Warped Dimension, BSM-LHC Workshop, Northeastern University, Boston, MA
• April 27-30, 2009, Aspects of Warped Phenomenology, LHC Theory Workshop, TRIUMF, Vancouver, BC, Canada
• The Galactic 511-keV Signal, Hidden Valleys, and Supernovae, Theory Seminar, SLAC (4/14), Columbia University (4/5), Boston University (2/1)
• Little Kaluza-Klein Modes at the LHC, Theory Seminar, Princeton University (11/9), University of California, Berkeley (10/26), Johns Hopkins University (9/29)
S. Dawson

- Jan 2009, INT Seattle, How Well do we know Higgs Properties?, Workshop on Measuring Higgs Couplings (2 talks)
- Feb12, 2009 CERN, EW Measurements and the 3 and 4-Site Models
- Feb 18, 2009 CERN, Implications of observation of a heavy Higgs Boson
- Aug. 3,4, 2009 SLAC Summer School, Introduction to Higgs Physics
- Sept 18, 2009, Waiting for the LHC, Colloquium, Emory U
- Nov 20, 2009, Theoretical Physics at BNL, talk to SUNY graduate students
- Dec 14,2009, Exploring Electroweak Symmetry Breaking, Quiggfest, Fermilab
- April 9, 2010, The Case for Electroweak Symmetry Breaking, City College Symposium on LHC Physics
- April 20, 2010, Higgs Bosons and b quarks, Theory seminar, Oklahoma State University
- April 20, 2010, The LHC and Beyond, Colloquium, Oklahoma State University
- May 9, 2010, The LHC and Beyond, Summary talk at PHENO10, Madison, WI
- May 12, 2010, b’s and Higgs Physics, Higgs Workshop, U. of Michigan
- July 29, 2010, Summary talk, Orsay Higgs workshop
T. Izubuchi

- December 2009, Lattice QCD: achievements and the future plans, Wako, Japan, RIKEN lattice QCD workshop
- July 2009, Renormalization factors of static quarks, Beijing, China, The XXVII International Symposium on Lattice Field Theory (LATTICE2009)
- March 2009, Results of Lattice Studies by the RBRC-UKQCD Collaboration, La Thuile, Italy, Rencontres de Moriond QCD and High Energy Interactions
- March 2009, The RBC/UKQCD light quark physics program: Meson result and future plans, Tsukuba, Perspectives on Light Quark Simulations through Machine, Algorithm and ILDG CCS
H. Lee

- Colloquium at University of Texas - Arlington (Apr. 2010), New force and the LHC
- Colloquium at University of Kansas (Feb. 2010), New force and the LHC
- UKC 2009 at Raleigh, NC (Jul. 2009), Stability mechanism for proton and dark matter
- SUSY 2009 at Boston, MA (Jun. 2009), New physics search via $Z'$ resonance
- Seminar at University of California - Riverside (May 2009), New physics search via $Z'$ resonance
- Seminar at Carleton University, Canada (Jan. 2009), U(1)'-extended Supersymmetric Standard Model
• Hidden Light Dark Matter in Neutrino Detectors, Seminar, Northeastern University, Apr. 26, 2010.
• Hidden Light Dark Matter in Neutrino Detectors, Seminar, Los Alamos National Laboratory, Jan. 14, 2010
• Light Hidden Fermionic Dark Matter in Neutrino Experiments, Workshop on Lepton and Baryon Number Violation, Madison, WI, Sept. 22, 2009.
• Hidden Dark Matter at Neutrino Experiments, Joint Particle Seminar, UC Irvine, May 6, 2009
• Light Hidden Fermionic Dark Matter in Neutrino Experiments, Meeting of the Division of Particles and Fields of the American Physical Society, Detroit, MI, July 31, 2009.
W. Kilgore

- Jan., 2010, Perturbative QCD and collider physics, WHEPP XI, Ahmedabad, India
- Jan., 2010, The W mass measurement, WHEPP XI, Ahmedabad, India
- May 2010, Higgs Systematics workshop, FNAL
W. Marciano

- Fundamental New Physics with Muons, Nucleons and Pions, PSI Keynote Director's Talk, Zurich, Switzerland, 2/19/09
- The Muon Anomalous Magnetic Moment and New Physics, Fermilab Colloquium, 4/28/09
- Charged Lepton Flavor Violation, Fermilab Academic Lectures (2), 4/29/09
- PAVI09 Conference Summary Talk, Bar Harbor, Maine, 6/26/09
- Muon Physics Overview, Neutrino Factory Workshop, Chicago, IL, 7/23/09
- Polarized Electron Scattering Lectures (2), Bosen, Germany, 9/4/09
- Electroweak Physics at the EIC, INT, Seattle, WA, 10/21/09
- Electromagnetic Dipole Moments, U. Mass Colloquium, 10/28/09
- Neutron Decay, Santa Fe Workshop, 11/6/09
Paige

- Talks to ATLAS Collaboration
  - JES from tracks  2010-04-26
  - Status of CONF note on jet reconstruction and calibration 2010-02-24
  - Summary on track based JES  2010-01-26
  - Study of jet energy scale from track 2010-01-20
  - Track-based jet energy scale results with 900GeV data 2010-01-12
  - Use of tracks to set the initial jet energy scale 2009-12-04
  - Gamma+jet studies  2009-08-04
  - Discussion about pile-up sensitive variables  2008-11-18
  - Low Mass Drell-Yan  2008-10-29 17:50:00

- Conference talks
  - H1 and Sampling Calibration for Jets" at the ATLAS Hadronic Calibration Workshop (Portugal, 2009)
  - Early Physics with ATLAS" at Particle Physics and Cosmology 2009 (Oklahoma).
A. Soni:

- March 2009, 4th generation, B-CP anomalies & the LHC, Moriond Electroweak Interactions, La Thuile, Italy
- March 2009, Clues from CP Studies for sub-TeV scale New Physics at the LHC, Interplay of Collider and Flavour Physics, CERN
- March 2009, Clues for TeV scale physics from B-CP anomalies, KEK Workshop on Hints for new physics in flavor decays, Tsukuba, Japan
- May 2009, Bs mixing & interpretations, FPCP09, Lake Placid, NY
- May 2009, 4th generation and B-CP anomalies, PHENO’09, Madison, WI
- July 2009, B-CP anomalies, 4th generation and the LHC, Europhysics 2009, Krakow, Poland
- Aug 2009, Hints of New Physics in B(Bs)-CP Asymmetries: May be we are eight now? DPF 2009, Detroit, MI
- Aug 2009, Lattice Weak Matrix Elements & CP violation: SM & Beyond, Workshop on “Universe in a Box: LHC, Cosmology and Lattice Field Theory”, Lorentz Center, International Center for workshops in the Sciences, Leiden, Netherlands
- Sept-Oct’09, B-CP anomalies, 4th generation & the LHC, Primosten 09: Progress and Challenges in Flavor Physics, Croatia, 9/29/09 to 10/03/09
- B-CP anomalies and sub-TeV signals at the LHC, invited talk at the Galileo Galilei Institute for Theoretical Physics, invited talk at the workshop on “Indirect Searches for New Physics at the time of LHC”, Feb 2010
C. Sturm

- Theory seminar, Fermilab, February 5, 2009, Heavy quark current correlators for precise quark masses and strong coupling constant
- LoopFest VIII, Madison, WI, May 7-9, 2009, Two-loop corrections and techniques for Higgs production and decay with massless gauge bosons
- Pheno 2009, May 11-13, 2009, Five-loop QED contributions for the anomalous magnetic moment of the muon
- DPF 2009, Detroit, July 26-31, 2009, Improving the precision of light quark mass determinations
- Theory seminar, University of Buffalo, February 3, 2010, Multi-loop results in QED for the anomalous magnetic moment of the muon
- Theory seminar, Karlsruhe, Germany, March 12, 2010, Improving the accuracy of quark mass determinations
- Invited talk, Spring Conference of the German Physical Society, Bonn, Germany, March 16, 2010, Precision determination of the charm- and bottom-quark mass.
- Pheno 2010, Madison, WI, May 10-12, 2010, Improving the precision of quark masses
- International Workshop on Heavy Quarkonia 2010, Fermilab, May 18-21, 2010, Precise determination of the charm- and bottom-quark mass
R. Van de Water:

- 29 October 2009, Unquenched lattice QCD calculations of $B \rightarrow D^{(*)}\ell\nu$ semileptonic form factors, Joint Workshop on $|V_{ub}|$ and $|V_{cb}|$, SLAC
- 30 October 2009, Lattice QCD calculations of $B \rightarrow \pi\ell\nu$ form factors, Joint Workshop on $|V_{ub}|$ and $|V_{cb}|$, SLAC
- 30 July 2009, The CKM matrix and flavor physics from lattice QCD, plenary talk at Lattice 2009, Peking University, China
- 29 May 2009, Status of CKM matrix elements from B-physics on the lattice, FPCP 2009, Lake Placid, NY
- 16 March 2009, Recent B-physics results from lattice QCD, Moriond QCD, La Thuile
- 11 February 2009, The $B \rightarrow \pi\ell\nu$ form factor and $|V_{ub}|$ from 2+1 flavor lattice QCD, Nuclear Physics Seminar, University of Maryland
- 10 February 2009, The $B \rightarrow \pi\ell\nu$ form factor and $|V_{ub}|$ from 2+1 flavor lattice QCD, Nuclear Physics Seminar, George Washington University
- 30 January 2009, The $B \rightarrow \pi\ell\nu$ form factor and $|V_{ub}|$ from 2+1 flavor lattice QCD, High Energy Physics Seminar, The Ohio State University
O. Witzel

- Neutral B-meson mixing from dynamical lattice QCD with chiral light quarks and static b-quarks, Lattice Conference Beijing, July 29, 2009
- B-meson decay constants, $B^0$-bt $B^0$-mixing and the $B^*B\pi$ coupling with domain-wall light quarks and relativistic heavy quarks, USQCD All Hands Meeting Upton, April 16, 2010