SLAC's Theoretical Physics Tradition

Lance Dixon
(SLAC)

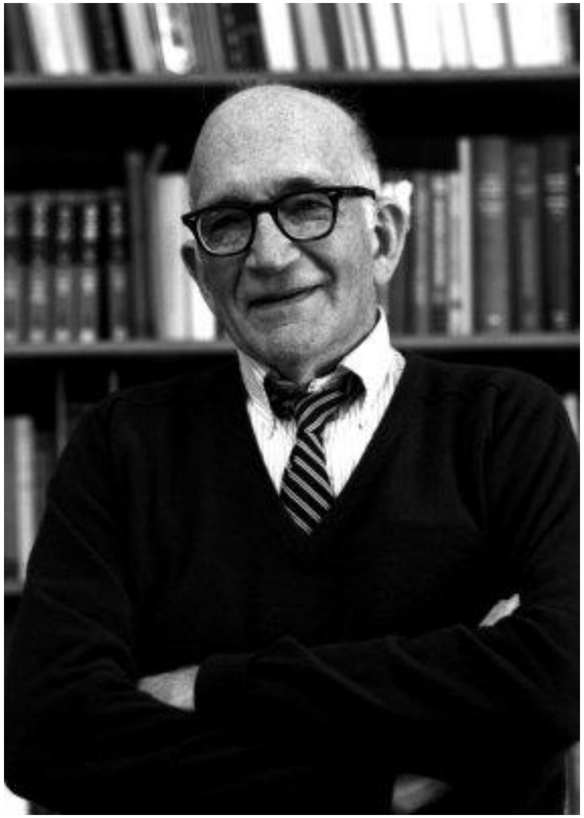
Symposium on Fundamental Physics in Memory of Sidney Drell

SLAC - Friday, January 12, 2018

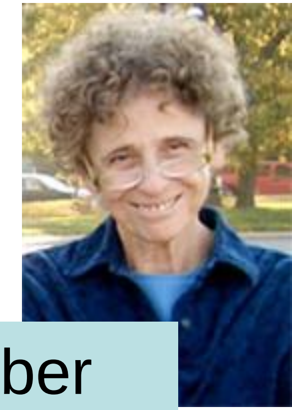
Qualities of Sid → SLAC Theory

- Open-ness
- Treated everyone equally and with respect
- No silos (stovepipes)
- Looong seminars
- Talk to experimenters

(even play softball with them)



Inge Karliner, graduate student circa 1971



Sid's warmth and accessibility were striking. I remember "My name is Sid!", in his loud voice, to anyone who called him "Professor Drell," be it students or secretaries. His office was always open to all. Sid's style helped made the theory group at SLAC supportive and friendly for all, including graduate students. Sid also organized talks by graduate students, where we learned, in a protected setting, to give talks and to think on our feet, with no faculty or postdocs allowed. The only PhD in the room was Sid, supportive and constructive in his responses.

http://www.slac.stanford.edu/history/IngaKarliner.shtml

No silos

- I came from Princeton, a hotbed of string theory (and, by 1986, not much other theory) to SLAC in 1986 as a fresh postdoc.
- By 1992 I had worked with string theorists [A. Sen, V. Kaplunovsky, J. Louis,…]
- But also neutrino/flavor physicists [Y. Nir]
- Skyrmions for neutron EDM [B. Warr, Y. Nir,…]
- Just starting to retool for pQCD [Z. Bern, D. Kosower,…]

No silos to the max:
SLAC theorists go off to do:

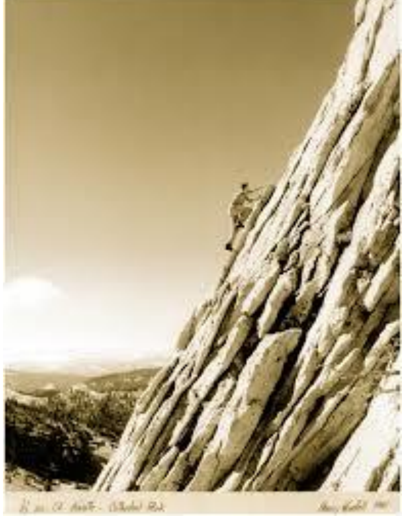
- Cosmology [J. Primack, A. Guth, J. Frieman, B. Ratra,…]
- Accelerator Physics [Blankenbecler & Drell, beamstrahlung;
  Bjorken, theory of intrabeam scattering]
- Deans, College Presidents [F. Gilman, P. Lepage, T. Appelquist, A. Falk,…]
- Lab Directors [C. Llewellyn-Smith, J. Bagger]
- World's best bond fund [M. Worah]
- Energy efficient lighting [S. Berman]

A few of SLAC theory's "greatest hits"

- Featuring "normal bias" and totally incomplete
- (Mostly) left out ones previous speakers may have covered.

$$x_{\mathrm{Bj}} = \frac{Q^2}{2Q\cdot p}$$

Bjorken scaling in DIS



PHYSICAL REVIEW VOLUME 148, NUMBER 4 26 AUGUST 1966

Applications of the Chiral $U(6)\otimes U(6)$ Algebra of Current Densities*

J. D. BJORKEN
Stanford Linear Accelerator Center, Stanford University, Stanford, California
(Received 14 March 1966)

PHYSICAL REVIEW VOLUME 179, NUMBER 5 25 MARCH

Asymptotic Sum Rules at Infinite Momentum*

J. D. BJORKEN
Stanford Linear Accelerator Center, Stanford University, Stanford, California
(Received 30 September 1968)

By combining the $q_0 \to i\infty$ method for asymptotic sum rules with the $P\to\infty$ method of Fubini and Furlan, we relate the structure functions W_2 and W_1 in inelastic lepton-nucleon scattering to matrix elements of commutators of currents at almost equal times at infinite momentum. We argue that the infinite-momentum limit for these commutators does not diverge, but may vanish. If the limit is nonvanishing, we predict $\nu W_2(\nu,q^2)\to f_2(\nu/q^2)$ and $W_1(\nu,q^2)\to f_1(\nu/q^2)$ as ν and q^2 tend to ∞. From a similar analysis for neutrino

From current algebra to seeing quarks (partons) in the proton

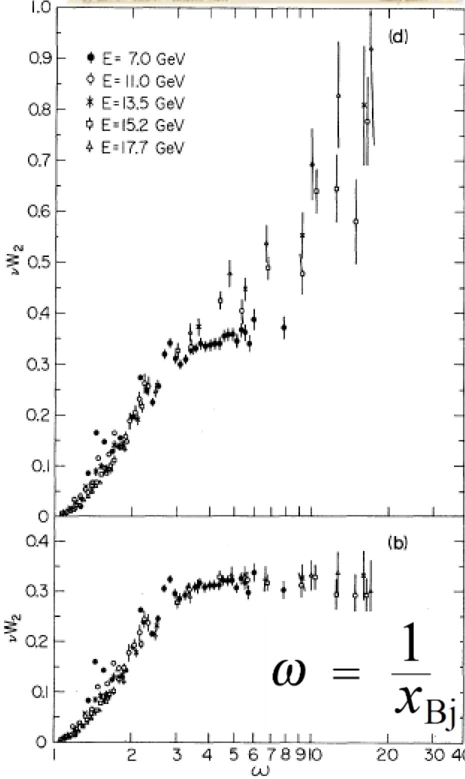
VOLUME 23, NUMBER 16 PHYSICAL REVIEW LETTERS 20 OCTOBER 1969

OBSERVED BEHAVIOR OF HIGHLY INELASTIC ELECTRON-PROTON SCATTERING

M. Breidenbach, J. I. Friedman, and H. W. Kendall
Department of Physics and Laboratory for Nuclear Science,*
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

and

E. D. Bloom, D. H. Coward, H. DeStaebler, J. Drees, L. W. Mo, and R. E. Taylor
Stanford Linear Accelerator Center,† Stanford, California 94305
(Received 22 August 1969)



$$\omega = \frac{1}{x_{\mathrm{Bj}}}$$

SLAC Theory 1969

Brodsky-Farrar

VOLUME 31, NUMBER 18 PHYSICAL REVIEW LETTERS 29 OCTOBER 1973

Scaling Laws at Large Transverse Momentum*

Stanley J. Brodsky
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

and

Glennys R. Farrar
California Institute of Technology, Pasadena, California 91109
(Received 14 August 1973)

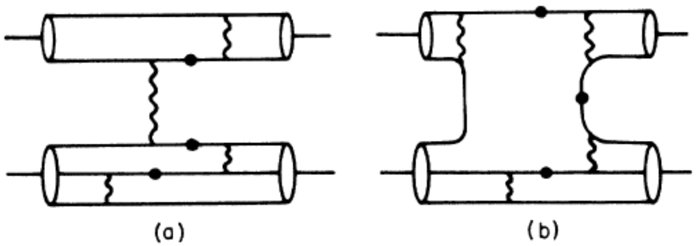
PHYSICAL REVIEW D VOLUME 11, NUMBER 5 1 MARCH 1975

Scaling laws for large-momentum-transfer processes*

Stanley J. Brodsky
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

Glennys R. Farrar
California Institute of Technology, Pasadena, California 91109
(Received 4 September 1974)

Asymptotic scaling
of exclusive hadronic processes



Peccei-Quinn symmetry

VOLUME 38, NUMBER 25 PHYSICAL REVIEW LETTERS 20 JUNE 1977

CP Conservation in the Presence of Pseudoparticles*

R. D. Peccei and Helen R. Quinn†
Institute of Theoretical Physics, Department of Physics, Stanford University, Stanford, California 94305
(Received 31 March 1977)

We give an explanation of the *CP* conservation of strong interactions which includes the effects of pseudoparticles. We find it is a natural result for any theory where at least one flavor of fermion acquires its mass through a Yukawa coupling to a scalar field which has nonvanishing vacuum expectation value.

The most compelling explanation of the strong CP problem (why the electric dipole moment of the neutron is so small) leads to a new particle, and leading dark matter candidate, the (invisible) axion

Eguchi, Gilkey and Hanson review

PHYSICS REPORTS (Review Section of Physics Letters) 66, No. 6 (1980) 213–393. NORTH-HOLLAND PUBLISHING COMPANY

GRAVITATION, GAUGE THEORIES AND DIFFERENTIAL GEOMETRY

Tohru EGUCHI*†

Stanford Linear Accelerator Center, Stanford, California 94305, USA

and

The Enrico Fermi Institute and Department of Physics††, The University of Chicago, Chicago, Illinois 60637, USA

Peter B. GILKEY**

Fine Hall, Box 37, Department of Mathematics, Princeton University, Princeton, New Jersey 08544, USA

and

Department of Mathematics††, University of Southern California, Los Angeles, California 90007, USA

and

Andrew J. HANSON*

Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, USA

and

P.O. Box 11693A††, Palo Alto, California 94306, USA

Received 19 March 1980

A personal favorite: Where I learned

a) nuts and bolts of differential geometry

b) An accelerator lab could be interested in formal topics

where Inflation was born

PHYSICAL REVIEW D VOLUME 23, NUMBER 2 15 JANUARY 1981

Inflationary universe: A possible solution to the horizon and flatness problems

Alan H. Guth*

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 11 August 1980)

The standard model of hot big-bang cosmology requires initial conditions which are problematic in two ways: (1) The early universe is assumed to be highly homogeneous, in spite of the fact that separated regions were causally disconnected (horizon problem); and (2) the initial value of the Hubble constant must be fine tuned to extraordinary accuracy to produce a universe as flat (i.e., near critical mass density) as the one we see today (flatness problem). These problems would disappear if, in its early history, the universe supercooled to temperatures 28 or more orders of magnitude below the critical temperature for some phase transition. A huge expansion factor would then result from a period of exponential growth, and the entropy of the universe would be multiplied by a huge factor when the latent heat is released. Such a scenario is completely natural in the context of grand unified models of elementary-particle interactions. In such models, the supercooling is also relevant to the problem of monopole suppression. Unfortunately, the scenario seems to lead to some unacceptable consequences, so modifications must be sought.

S and T parameters:

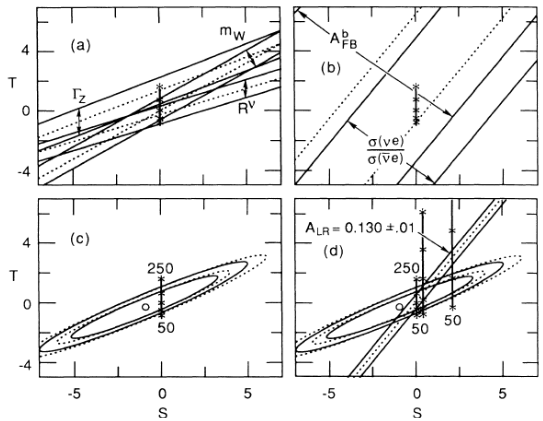
Precision EW constraints on BSM Physics

VOLUME 65, NUMBER 8 PHYSICAL REVIEW LETTERS 20 AUGUST 1990

New Constraint on a Strongly Interacting Higgs Sector

Michael E. Peskin and Tatsu Takeuchi
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309
(Received 13 June 1990)

We show that an integral S over the spectral function of spin-1 states of the Higgs sector is constrained by precision weak-interaction measurements. Current data exclude large technicolor models; asymmetry measurements at the CERN e^+e^- collider LEP and the SLAC Linear Collider will soon provide more stringent limits on Higgs-boson strong interactions.



PHYSICAL REVIEW D VOLUME 46, NUMBER 1 1 JULY 1992

Estimation of oblique electroweak corrections

Michael E. Peskin and Tatsu Takeuchi
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309
(Received 9 December 1991)

wrote a pretty good textbook too

SLAC Theory circa 1992

Large extra dimensions

The hierarchy problem and new dimensions at a millimeter

Nima Arkani–Hamed [a], Savas Dimopoulos [b], Gia Dvali [c]

[a] *SLAC, Stanford University, Stanford, CA 94309, USA*
[b] *Physics Department, Stanford University, Stanford, CA 94305, USA*
[c] *ICTP, Trieste 34100, Italy*

Received 12 March 1998; revised 8 April 1998
Editor: H. Georgi

Abstract

We propose a new framework for solving the hierarchy problem which does not rely on either supersymmetry or technicolor. In this framework, the gravitational and gauge interactions become united at the weak scale, which we take as the only fundamental short distance scale in nature. The observed weakness of gravity on distances $\gtrsim$ 1 mm is due to the existence of $n \geq 2$ new compact spatial dimensions large compared to the weak scale. The Planck scale $M_{Pl} \sim G_N^{-1/2}$ is not a fundamental scale; its enormity is simply a consequence of the large size of the new dimensions. While gravitons can freely propagate in the new dimensions, at sub-weak energies the Standard Model (SM) fields must be localized to a 4-dimensional manifold of weak scale "thickness" in the extra dimensions. This picture leads to a number of striking signals for accelerator and laboratory experiments. For the case of $n = 2$ new dimensions, planned sub-millimeter measurements of gravity may observe the transition from $1/r^2 \to 1/r^4$ Newtonian gravitation. For any number of new dimensions, the LHC and NLC could observe strong quantum gravitational interactions. Furthermore, SM particles can be kicked off our 4 dimensional manifold into the new dimensions, carrying away energy, and leading to an abrupt decrease in events with high transverse momentum $p_T \gtrsim$ TeV. For certain compact manifolds, such particles will keep circling in the extra dimensions, periodically returning, colliding with and depositing energy to our four dimensional vacuum with frequencies of $\sim 10^{12}$ Hz or larger. As a concrete illustration, we construct a model with SM fields localized on the 4-dimensional throat of a vortex in 6 dimensions, with a Pati-Salam gauge symmetry $SU(4) \times SU(2) \times SU(2)$ in the bulk.

Unitarity Method

ELSEVIER

Nuclear Physics B425 (1994) 217–260

NUCLEAR PHYSICS B

One-loop n-point gauge theory amplitudes, unitarity and collinear limits

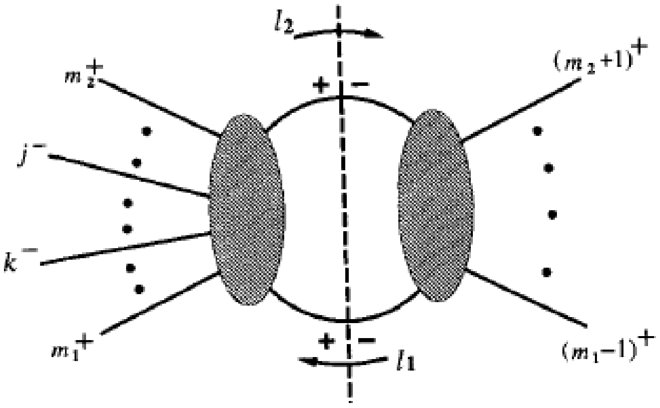
Zvi Bern [a,1], Lance Dixon [b,2], David C. Dunbar [a,3], David A. Kosower [c,4]

[a] *Department of Physics, UCLA, Los Angeles, CA 90024, USA*
[b] *Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA*
[c] *Service de Physique Théorique de Saclay, Centre d'Etudes de Saclay, F-91191 Gif-sur-Yvette cedex, France*

Received 11 March 1994; accepted for publication 6 April 1994

Abstract

We present a technique which utilizes unitarity and collinear limits to construct ansätze for one-loop amplitudes in gauge theory. As an example, we obtain the one-loop contribution to amplitudes for n-gluon scattering in $N = 4$ supersymmetric Yang–Mills theory with the helicity configuration of the Parke–Taylor tree amplitudes. We prove that our $N = 4$ ansatz is correct using general properties of the relevant one-loop n-point integrals. We also give the "splitting amplitudes" which govern the collinear behavior of one-loop helicity amplitudes in gauge theories.



Unitarity merged with perturbation theory to make (multi)-loop amplitude calculations practical for QCD at LHC, supergravity, ...

Reverse unitarity

Higgs boson production at hadron colliders in NNLO QCD

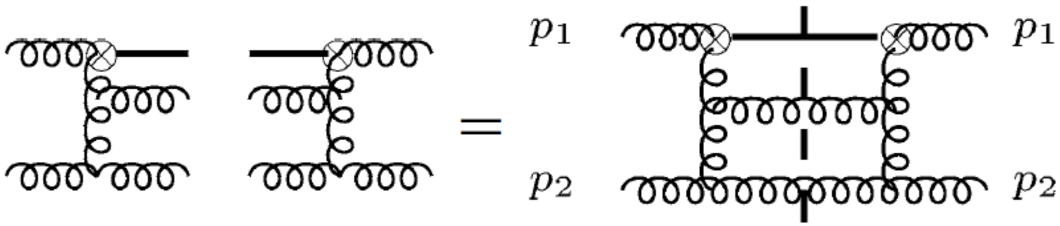
Charalampos Anastasiou, Kirill Melnikov

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA

Received 9 July 2002; received in revised form 4 September 2002; accepted 19 September 2002

Abstract

We compute the total cross-section for direct Higgs boson production in hadron collisions at NNLO in perturbative QCD. A new technique which allows us to perform an algorithmic evaluation of inclusive phase-space integrals is introduced, based on the Cutkosky rules, integration by parts and the differential equation method for computing master integrals. Finally, we discuss the numerical impact of the $\mathcal{O}(\alpha_s^2)$ QCD corrections to the Higgs boson production cross-section at the LHC and the Tevatron.




The BEST paper

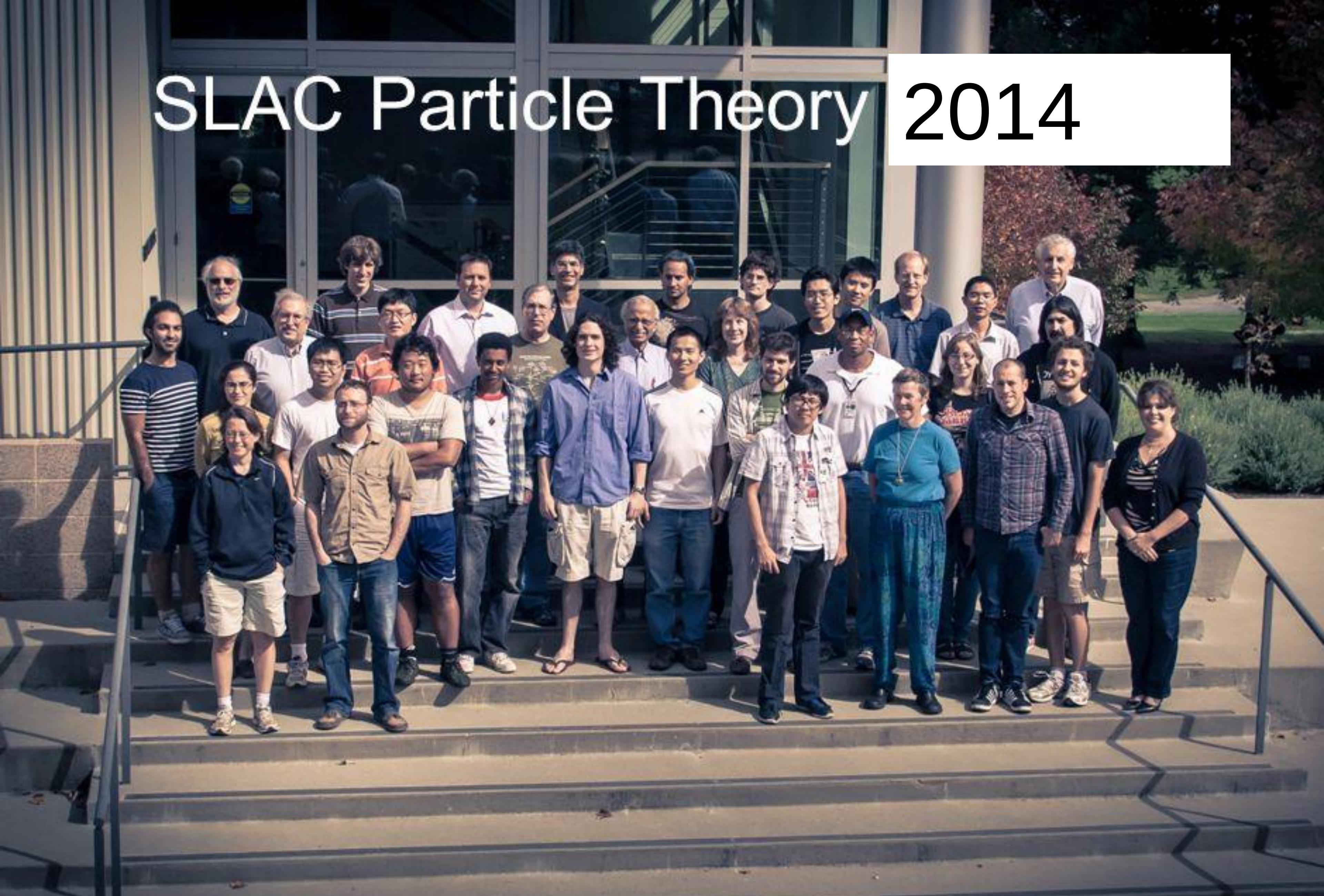
PHYSICAL REVIEW D **80,** 075018 (2009)

New fixed-target experiments to search for dark gauge forces

James D. Bjorken,[1] Rouven Essig,[1] Philip Schuster,[1] and Natalia Toro[2]
[1]*Theory Group, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA*
[2]*Theory Group, Stanford University, Stanford, California 94305, USA*
(Received 20 July 2009; published 28 October 2009)

Fixed-target experiments are ideally suited for discovering new MeV–GeV mass $U(1)$ gauge bosons through their kinetic mixing with the photon. In this paper, we identify the production and decay properties of new light gauge bosons that dictate fixed-target search strategies. We summarize existing limits and suggest five new experimental approaches that we anticipate can cover most of the natural parameter space, using currently operating GeV-energy beams and well-established detection methods. Such experiments are particularly timely in light of recent terrestrial and astrophysical anomalies (PAMELA, Fermi, DAMA/LIBRA, etc.) consistent with dark matter charged under a new gauge force.

Searching for dark matter sectors in the laboratory



J. Hewett July 2014

Open doors, even windows

Loooong Seminars in the Green Room

- My "job talk" in 1985 went for over 2 hours
- Always talk of getting a chess clock (but never did)
- Sid's seminar strategy

"SLAC theorists discuss methods for analyzing the production of supersymmetric particles at the LHC (2008)"

Softball with experimenters

Lynn?, Ballam, Polchinski, Haber, Drell, Ward

Drell-Richter Trophy

Softball with experimenters

1997, a very good year – theory won for 5th time in 9 years!

Congratulatory fax from Deputy Consul General Peter Hof, Consulate General of Switzerland in San Francisco to Prof. Stanley Brodsky, Head of SLAC Theory Group:

"Unfortunately, the sports pages of local journals did not mention the sensational result of this year's baseball game between your team, which should have, theoretically, lost, and the team of the experimentalists of [SLAC]. Dr. Christoph Greub [SLAC 1994-1996] informed me however that the well elaborated game plan you worked out allowed you and your team to win this prestigious game last Saturday. I would like to congratulate your team on this success and I hope that next year's result will be again positive."

Post-softball party at Sid & Harriet's

Shimon Yankielowicz, postdoc circa 1974

Shimon: Look, I think, I believe, maybe ... there is one mistake of some factor in this formula in your book [Bjorken & Drell].

Sid: Say no more, I'll assume you are right and this is the only mistake in the book. How much did you pay for the book in Israel?

Shimon: I'm not sure, I do not remember...

Sid [hands Shimon a quarter]: I think this will compensate you for buying defective goods, a book which carries one mistake. It's roughly the royalty I get for each book.

http://www.slac.stanford.edu/history/ShimonY.shtml

Qualities of Sid → SLAC Theory

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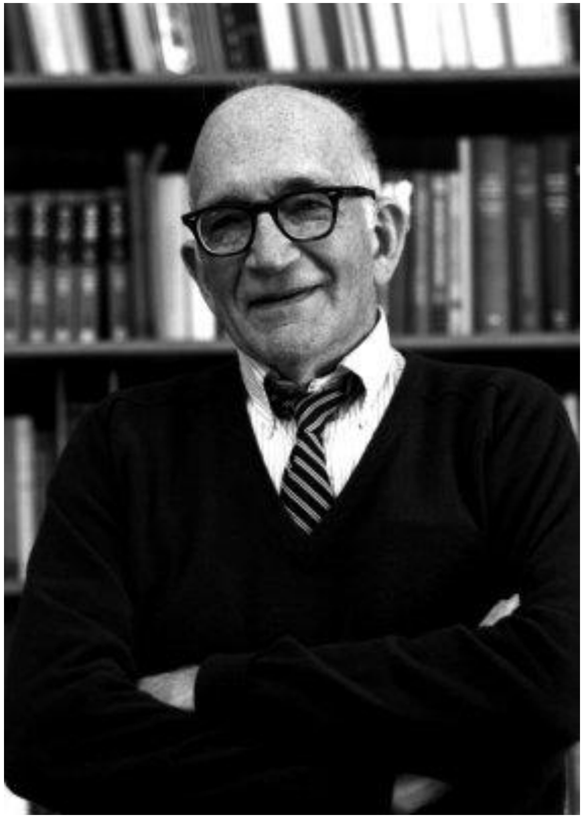
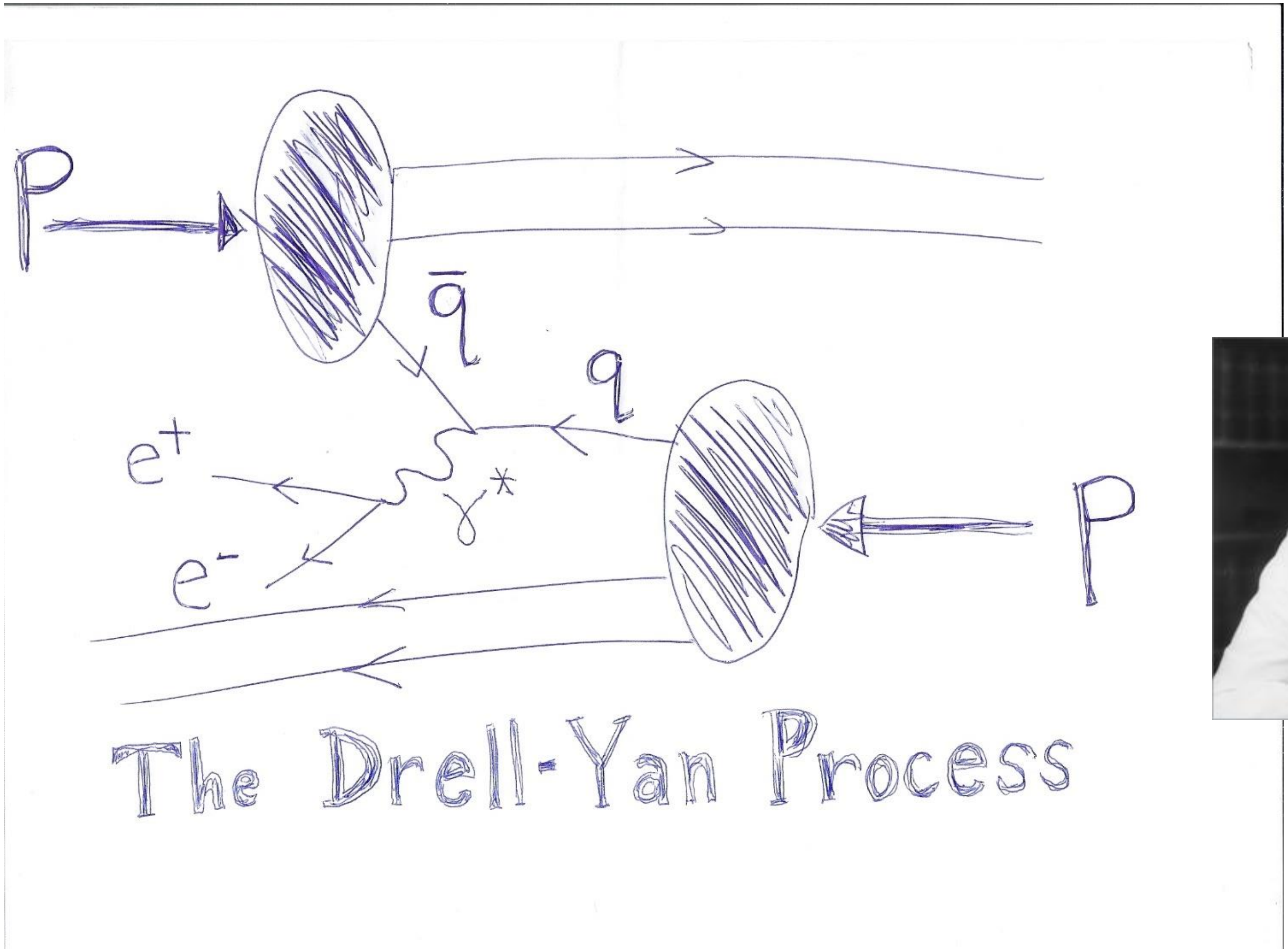
(even play softball with them)



Formula for outstanding theoretical physics over the past half century


P
$\bar{q}$
q
e^+
e^-
γ^*
P
The Drell-Yan Process