The High Energy Physics group consists of four faculty experimentalists and four faculty theoreticians, as well as several postdoctoral research fellows, and other personnel supporting research including a research scientist, an IT specialist, and an engineer.

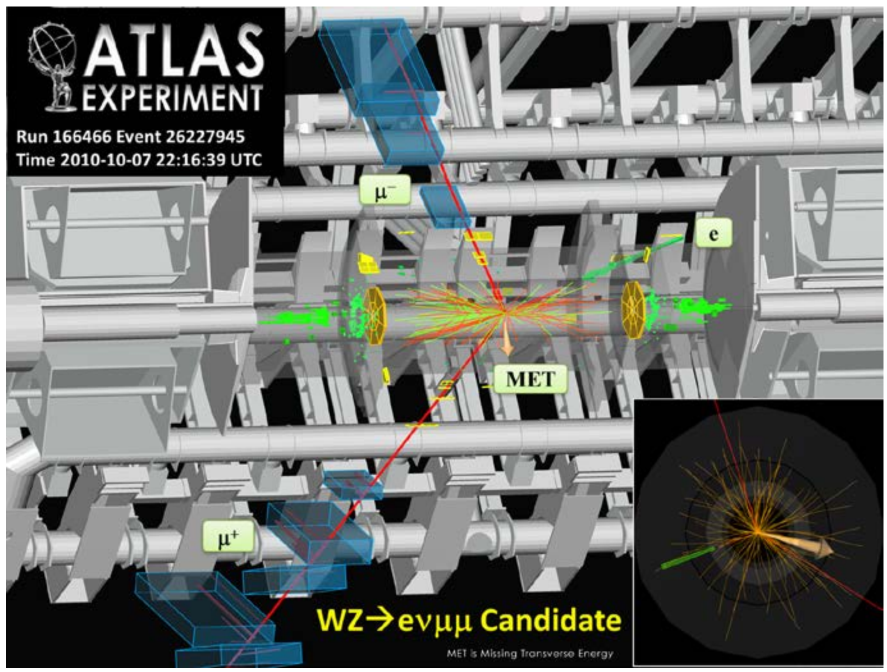
The goals of the experimental high energy physics group are to search for new physics and to explore the predictions of the Standard Model to unprecedented accuracy. In order to perform this research, we are involved in the DØ experiment at Fermilab (near Chicago) and the ATLAS experiment at the Large Hadron Collider (LHC) at CERN. While DØ continues to analyze data, the ATLAS experiment is taking data and should continue to be one of the premiere instruments for scientific discovery for decades to come.

The DØ experiment analyzes data taken at the Fermilab Tevatron with the world's highest energy proton antiproton collisions, which can be used to study the strong (QCD) and electroweak interactions through the decays of the produced particles and through their measured angular distributions. Some of the recent results from the DØ experiment include the discovery of the top quark, a precision measurement of the W mass, and gluon radiation interference effects. In addition, numerous searches for new particles, new forces and discrepancies with the Standard Model are all being carried out. For the next few years new physics discoveries will continue to be pursued at one of the premier detectors in the world.

The LHC is the highest energy proton-proton collider ever constructed, eventually with a collision energy of 14 TeV. These energetic collisions are expected to probe some of the most fundamental questions in the universe. Questions regarding the origin of mass, the dark matter in the universe, and the abundance of matter over anti-matter may be answered at the LHC. We will look for more fundamental structure within the quarks and leptons that make up our universe and probe fundamental questions about supersymmetry, string theory, and extra dimensions. Though definitive answers to these questions are far from certain, the energy and collision rate of the LHC should make it one of the most exciting scientific tools ever built by humans.

Besides the direct physics research, we have also been involved in state-of-the-art detector development for the DØ and the ATLAS experiment. This program, which uses our own facilities at OU, focuses on advanced silicon micro-strip detectors. The excellent position resolution of silicon allows identification of short-lived particles and allows us to measure their properties.

The theoretical group is studying non-perturbative aspects of quantum field theory (QFT) and gauge theories. QFT is the basic framework for the description of particle physics, as well as for many other areas of physics. The calculations required today to solve field theories cannot be done by considering relatively small corrections (perturbations) to non-interacting theories of quarks and gluons, for example. In particular, non-perturbative methods are essential to understand the phenomena of strong interactions. Thus new mathematical methods are required, some of which are being developed in our group. In addition to developing new types of perturbative expansions and approximation methods, as well as studying new types of quantum field theories, analytical calculations are being applied to a number of important particle physics topics: quantum chromodynamics, quantum electrodynamics, the Casimir effect (vacuum fluctuations).



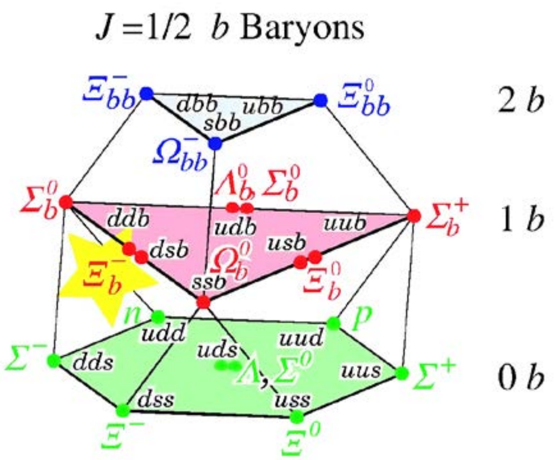
A major focus of our HEP theory group is at the theory/experiment interface, called phenomenology. Theorists are investigating QCD, the electroweak theory, and prospects for the detection of Higgs bosons at colliding beam machines such as the LHC and the future International Linear Collider. We are also active in exploring physics ideas that go beyond the Standard Model, such as grand unified theories, supersymmetry, string theory and the possibility of extra spacetime dimensions. Theorists in our group have been pioneers in calculating production and decay rates for new superparticle matter states at LHC and other colliders. We also examine ideas at the particle physics/cosmology interface, especially issues such as dark matter candidate particles and their production in the early universe, and dark matter detection at underground or space-based facilities.

[Brad Abbott]

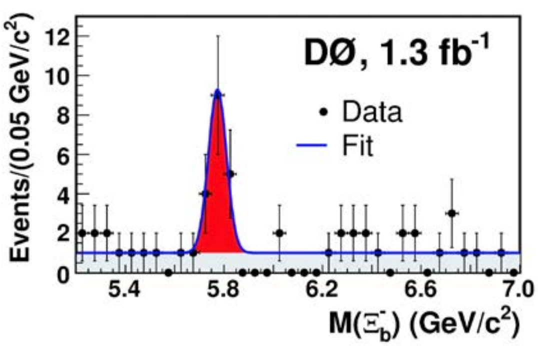
associate professor

B.A. 1989 University of Minnesota, Morris

Ph.D. 1994 Purdue University



The family of J=1/2 b baryons indicating the newly discovered Ξ_b^- quark content.



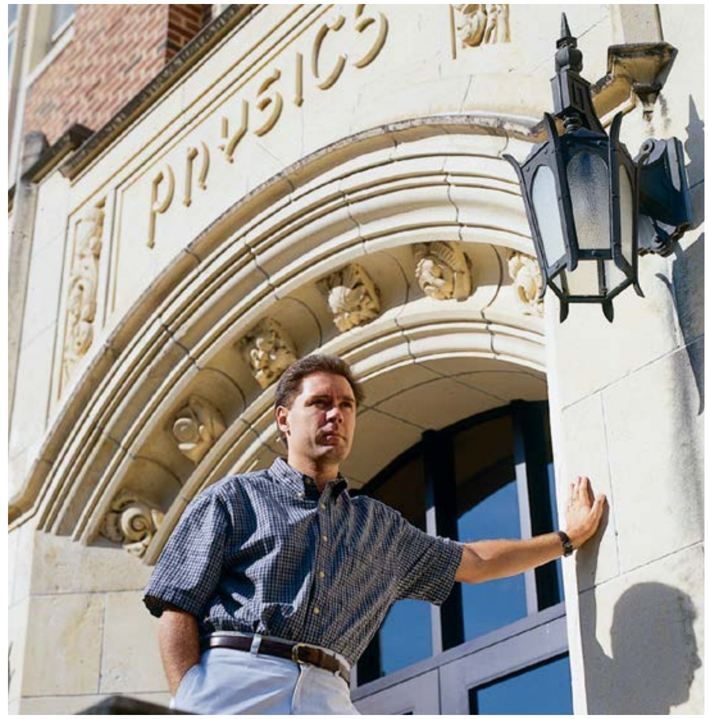
Invariant mass distribution of the recently discovered Ξ_b^- baryon.

"Measurement of the Relative Branching Ratio of $B_s \to J/\psi f_0$,"(980) to $B_s \to J/\psi\, \varphi$" *Phys. Rev. D* **85,** 011103 (2012).

"Observation of the Doubly Strange *b* Baryon Ω_b^-", *Phys. Rev. Lett,* **101,** 232002 (2008).

"Direct observation of the strange b baryon Ξ_b^-" *Phys. Rev. Lett.* **99,** 052001 (2007).

"Direct Limits on the B_s^0 Oscillation Frequency," *Phys. Rev. Lett.* **97,** 021802 (2006)



My research in experimental particle physics has recently been in heavy flavor physics, which includes both the bottom and the top quark. I am a member of the DØ collaboration at the Fermi National Accelerator Laboratory, which is located near Chicago Illinois. At DØ, I have studied properties of the B meson, and in particular B_s mixing, which involves a B_s meson oscillating into its anti-matter partner. I have also been active in studying various particles including the X(3872), and the Ξ_b^- and Ω_b baryons. Most recently I have been studying CP violation by studying the decays $B_s \to J/\psi f_0$(980) and $B_s \to J/\psi f_2'$ (1525).

I am also a member of the ATLAS collaboration at the Large Hadron Collider(LHC) located near Geneva Switzerland. The ATLAS detector has been collecting data since 2010 and has accumulated a large data set at the world's highest center of mass energy. The LHC is one of the best places to search for new physics beyond the Standard Model, so I have primarily been involved in studying Super Symmetry to search for super-symmetric partners to the currently known forms of matter. With the discovery of the Higgs Boson, the LHC has hopefully just started on its path of many more discoveries.

[Howard A. Baer]

Professor

Homer L. Dodge Professor of High Energy Physics

American Physical Society Fellow

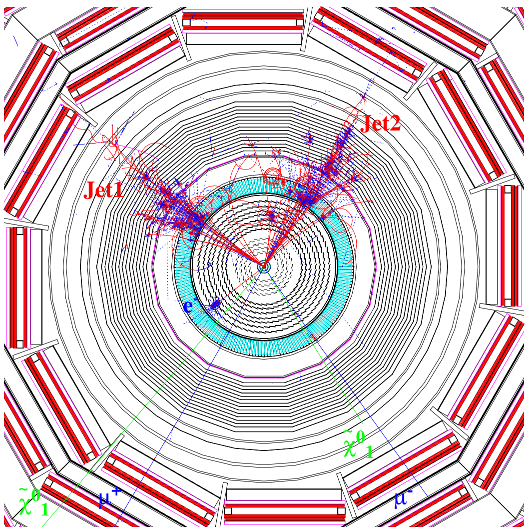
B.S. 1979 University of Wisconsin

M.S. 1981 University of Wisconsin

Ph.D. 1984 University of Wisconsin

SUSY event with 3 lepton + 2 Jets signature

m_0 = 100 GeV, $m_{1/2}$ = 300 GeV, $\tan\beta$ = 2, A_0 = 0, $\mu < 0$,
$m(\tilde{q})$ = 686 GeV, $m(\tilde{g})$ = 766 GeV, $m(\tilde{\chi}^0_2)$ = 257 GeV,
$m(\tilde{\chi}^0_1)$ = 128 GeV.



Leptons:	Jets:	Sparticles:
$p_t(\mu^+)$ = 55.2 GeV	E_t(Jet1) = 237 GeV	$p_t(\tilde{\chi}^0_1)$ = 95.1 GeV
$p_t(\mu^-)$ = 44.3 GeV	E_t(Jet2) = 339 GeV	$p_t(\tilde{\chi}^0_1)$ = 190 GeV
$p_t(e^-)$ = 43.9 GeV		

Charged particles with $p_t > 2$ GeV, $|\eta| < 3$ are shown;
neutrons are not shown; no pile up events superimposed.

"Coupled Boltzmann calculation of mixed axion/neutralino cold dark matter production in the early universe," Howard Baer, Andre Lessa and Warintorn Sreethawong, *JCAP* **1201,** 036 (2012).

"Implications of a 125 GeV Higgs scalar for LHC SUSY and neutralino dark matter searches," Howard Baer, Vernon Barger and Azar Mustafayev, *Phys. Rev.* **D85,** 075010 (2012).

"Post LHC7 SUSY benchmark points for ILC physics," Howard Baer and Jenny List, *arXiv:1205.6929*

"Radiative natural SUSY with a 125 GeV Higgs boson," Howard Baer, Vernon Barger, Peisi Huang, Azar Mustafayev and Xerxes Tata, *arXiv:1207.3343*

Weak Scale Supersymmetry: From Superfields to Scattering Events, Howard Baer and Xerxes Tata, Cambridge University Press (2006).

My research interests lie at the interface of theoretical and experimental High Energy Physics, basically matching the predictions of theory against experimental data. I am especially interested in physics beyond the Standard Model, as given by theories with weak scale supersymmetry (SUSY). These theories predict a symmetry between bosons and fermions, and so each particle of the Standard Model is expected to have a superpartner particle differing in spin, and with mass of order the TeV scale.

My collaborators and I have developed the first computer code to reliably predict what supersymmetric matter states would look like in colliding beam machines such as the LHC. The LHC should have enough energy to either discover SUSY or rule out many of its manifestations.

I also work on the cosmology/particle physics interface, and have developed code to estimate the relic abundance of dark matter from the Big Bang in SUSY theories. We have also calculated rates for direct and indirect detection of WIMP (weakly interacting massive particles) dark matter. Recently, we are most interested in the consequences of mixed axion/neutralino cold dark matter.

Lately, I am especially interested in theories of ``natural supersymmetry'' with mixed axion-higgsino cold dark matter, and how this could be reevaled at LHC or at an International Linear e+e- Collider (ILC).

[Phillip Gutierrez]

professor

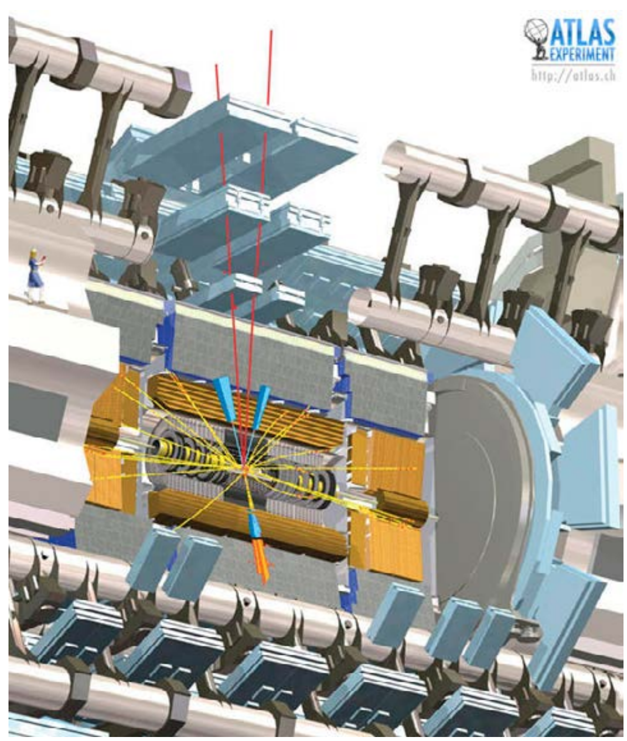
B.S. 1976 University of California

Ph.D. 1983 University of California-Riverside

Over the past 20 plus years, I have carried out research in experimental high energy physics. The research has been performed at two of the premier high energy physics laboratories in the world, Fermilab near Chicago and the CERN laboratory near Geneva, Switzerland. Currently I am a member of the DØ collaboration,one of two research groups that use the Fermilab Tevatron, currently the world's highest energy particle collider. The goal of the research is to study all aspects of proton/anti-proton collisions. This includes studying particles that are produced in these collisions, such as the top-quark, and refining previous measurements to set limits on how well the standard model of particle physics agrees with data. These measurements will ultimately lead to extensions of the standard model, which should help answer such questions as the origin of mass and the asymmetry between matter and anti-matter in the universe, among many others.

At the present time, I am participating in measurements of top-quark production and using these measurements to set limits on the existence of Higgs particles that may exist in extensions to the standard model of particle physics. In the past I have carried out physics analyses that involve QCD (strong interactions) and electroweak interactions.

With the start up of the Large Hadron Collider at the CERN laboratory, I have begun to move my research effort to exploring the data that will be made available in the near future using the ATLAS detector. For the moment my plan is to extend the research that I am currently carrying out at Fermilab using the top-quark as a probe of the standard model of particle physics.



This figure shows a computer simulation of what a Higgs boson particle would look like in the ATLAS detector at the Large Hadron Collider.

V.M. Abazov, *et al,* DØ Collaboration, "Search for charged Higgs bosons in decays of top quarks," *Phys. Rev. D,* **80,** 051107 (2009).

V.M. Abazov, *et al,* DØ Collaboration, "Measurement of the Angular and Lifetime Parameters of the Decays $B_d^0 \to J/\psi\ K^{*0}$ and $B_s^0 \to J/\psi\ \varphi$," *Phys. Rev. Lett.,* **102,** 032001 (2009).

V.M. Abazov, *et al,* DØ Collaboration, "Measurement of the B_s^0 Mixing Parameters from the Flavor-Tagged Decay $B_s^0 \to J/\psi\ \varphi$," *Phys. Rev. Lett.,* **101,** 241801 (2008).

V.M. Abazov, *et al,* DØ Collaboration, "Search for Anomalous *Wtb* Couplings in Single Top Quark Production," *Phys. Rev. Lett.,* **101,** 221801 (2008).

V.M. Abazov, *et al,* DØ Collaboration, "Search for Production of Single Top Quarks via *tcg* and *tug* Flavor Changing-Neutral-Current Couplings," *Phys. Rev. Lett.,* **99,** 191802 (2007).

V.M. Abazov, *et al,* DØ Collaboration, "Evidence for production of single top quarks and first direct measurement of $|V_{tb}|$," *Phys. Rev. Lett.,* **98**, 181902 (2007).

V.M. Abazov, et al, DØ Collaboration, "Lifetime Difference and CP-Violating Phase in the B_s^0 System", *Phys. Rev. Lett.,* **98,** 121801 (2007).

V.M. Abazov, et al, DØ Collaboration, "Combined DØ measurements constraining the CP-violating phase and width difference in the B_s^0 system", *Phys. Rev. D* **76,** 057101 (2007).

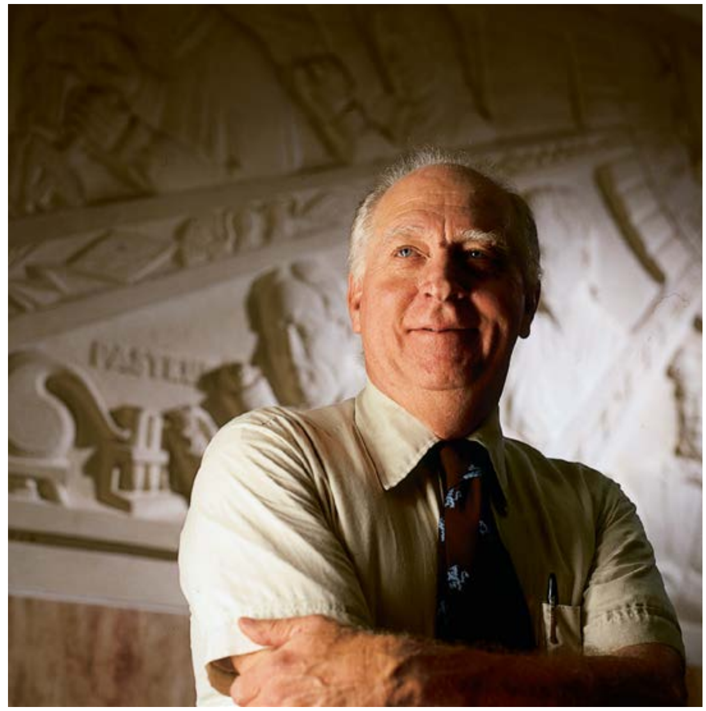
[Ronald Kantowski]

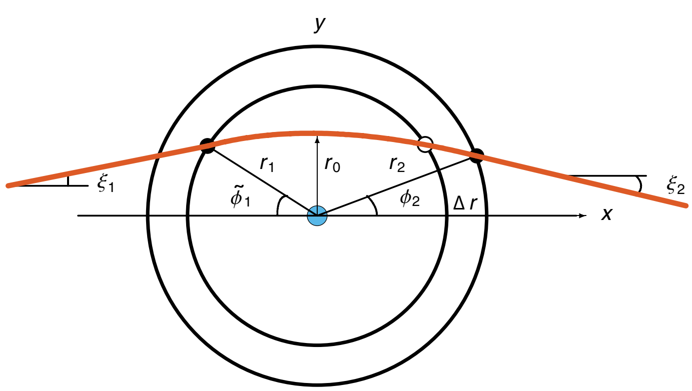
professor

B.S. 1962 University of Texas

Ph.D. 1966 University of Texas

My current interests are in cosmology. With colleagues we are looking at nonlinear gravitational lensing corrections caused by embedding inhomogeneities (galaxies, clusters, etc.) in otherwise homogeneous models of the universe. To find nonlinear effects such as the cosmological constant's alteration of Einstein's bending angle, we found it necessary to use the exact GR solution called Swiss cheese models. In other projects we have managed to incorporate absorption into Gordon's optical metric on space time and are revisiting time delays in gravitational lensing, hoping to find new observational opportunities.





A photon travels left to right entering a void in the homogeneous cosmology caused by a point mass condensation (the embedded lens) at point 1 and returns to the homogeneous background at point 2. Due to the cosmological expansion the void's radius $\Delta r \equiv r_2 - r_1 > 0$ increases as the photon passes. The resulting deflection angle $\alpha = \xi_2 - \xi_1$ is reduced compared to conventional point mass lensing because the condensation attracts the passing photon only while it is in the void. The effect of the cosmological constant Λ on α occurs because Λ effects the expansion rate of the void's boundary hence extending the photons stay in the expanding void. The most significant terms in the embedded lens α are:

$$\alpha = -\frac{2r_s}{r_0}\cos^2\tilde{\phi}_1\left[\cos\tilde{\phi}_1 + 3\sin\tilde{\phi}_1\sqrt{\frac{\Lambda r_0^2}{3} + \frac{r_s}{r_0}\sin\tilde{\phi}_1}\right]$$

R. Kantowski, B. Chen, & X. Dai, "Image Properties of Embedded Lenses," *Phys. Rev. D* **86**, 043009 (2012).

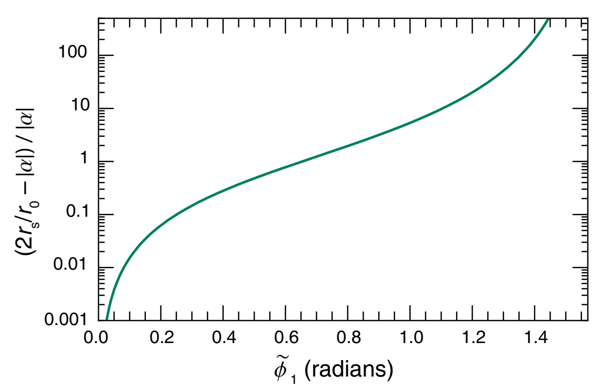
B. Chen, R. Kantowski, & X. Dai, "Gravitational lens equation for embedded lenses; magnification and ellipticity," *Phys. Rev. D* **84**, 083004 (2011).

B. Chen, R. Kantowski, & X. Dai, "Time delay in Swiss cheese gravitational lensing," *Phys. Rev. D* **82**, 043005 (2010) .

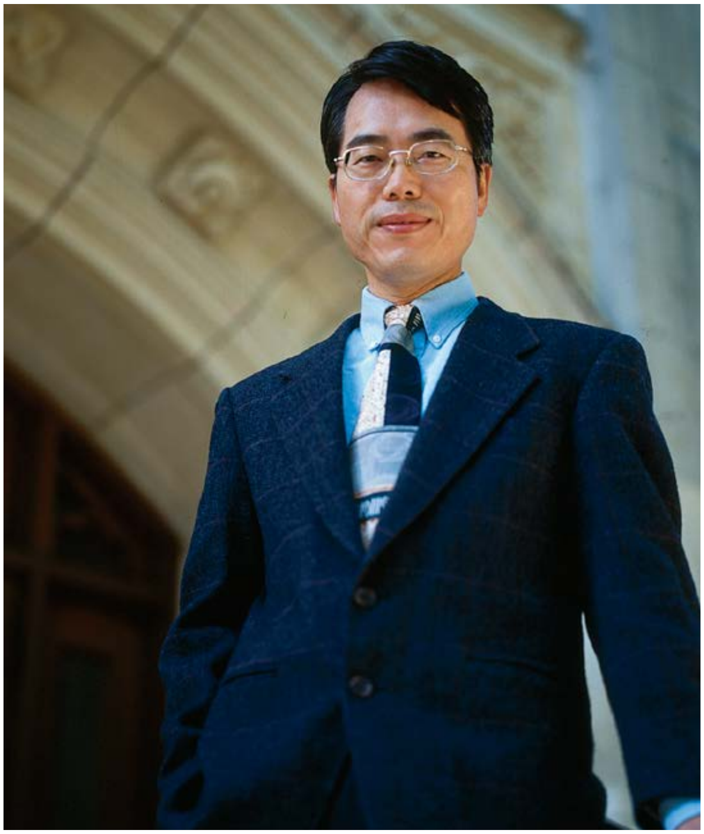
R. Kantowski, B. Chen, & X. Dai, "Gravitational Lensing Corrections in Flat Lambda-CDM Cosmology," *Astrophysical J.* **718**, 913 (2010).

B. Chen & R. Kantowski, "Distance redshift from an optical metric that includes absorption," *Phys. Rev. D* **80**, 044019 (2009).

B. Chen & R. Kantowski, "Including Absorption in Gordon's Optical Metric," *Phys. Rev. D* **79**, 104007 (2009).



The fractional difference of the Einstein deflection angle $2r_s/r_0$ and the embedded lens deflection α, i.e., $(2r_s/r_0 - |\alpha|)/|\alpha|$ as a function of $\tilde{\phi}_1$ in radians. For the domain of $\tilde{\phi}_1$ plotted and to the accuracy shown, the fractional error is remarkably independent of the mass of the deflector (10^{11}–10^{15} $M_\odot$) and its redshift ($0 < z < 2$).



[Chung Kao]

associate professor

B.S. 1980 National Taiwan Normal University
M.S. 1984 The University of Oregon
Ph.D. 1990 The University of Texas

My research interests are in theoretical high energy physics, astrophysics and cosmology, especially Electroweak Symmetry Breaking (EWSB), supersymmetry, unification of fundamental interactions, CP Violation, dark matter, and theories with extra dimensions. One of the most important goals of future colliders is to discover the Higgs bosons or to prove their nonexistence. In the Standard Model of electroweak interactions, the Higgs field condenses (disappears into the vacuum), spontaneously breaking the electroweak symmetry and generating masses for the elementary particles. Weak scale supersymmetry is the most compelling extension of the Standard Model to preserve the elementary nature of the Higgs bosons. In most supersymmetric models, the lightest neutralino can be a good cold dark matter candidate if R-parity is conserved. Recently, I have been investigating direct and indirect signatures of new physics in present and future experiments to pursue interesting physics of electroweak symmetry breaking, supersymmetry, CP violation and astrophysics.

D.A. Dicus, C. Kao, S. Nandi, J. Sayre, "Discovering Colorons at the Early Stage LHC," *Phys. Rev. D* **83**, 091702 (2011).

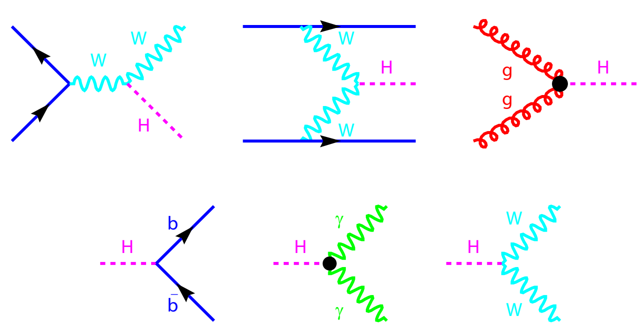
S. Dawson, C. Kao and Y. Wang, "SUSY QCD Corrections to Higgs Pair Production from Bottom Quark Fusion," *Phys. Rev. D* **77**, 113005 (2008).

S. Dawson, D. Dicus, C. Kao and R. Malhotra, "Discovering the Higgs Bosons of Minimal Supersymmetry with Mousons and a Bottom Quark," *Phys. Rev. Lett.* **92**, 241801 (2004).

V. Barger and C. Kao, "Implications of new CMB data for nutralino dark matter," *Phys. Lett. B* **518**, 117 (2001).

V. Barger, T. Han, C. Kao and R. J. Zhang, "Astrophysical Constraints on Large Extra Dimensions," *Phys. Lett. B* **461**, 34 (1999).

A. Das and C. Kao, "A Two Higgs Doublet Model for the Top Quark," *Phys. Lett. B* **372**, 106 (1996).



Production and decay modes for the Higgs particle.

[Kimball A. Milton]

professor

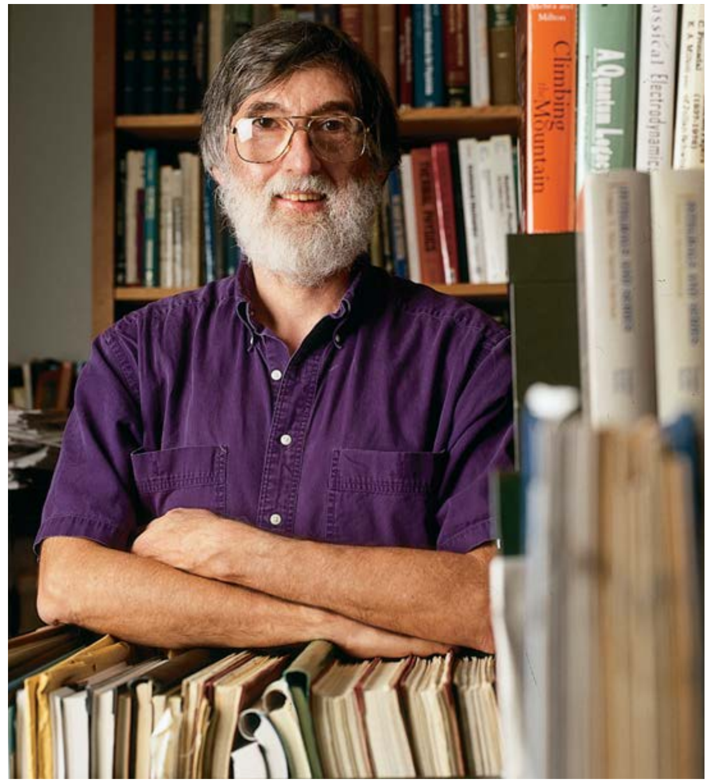
George Lynn Cross Research Professor

Fellow, Institute of Physics (UK)

Foreign Member, Royal Norwegian Society of Letters and Science

B.S. 1967 University of Washington

Ph.D. 1971 Harvard University



The interactions that give rise to the structure of atoms, nuclei, and elementary particles are described by quantum gauge field theories. These gauge theories are Abelian in the case of electrodynamics (photons do not interact with each other), and are non-Abelian in the case of weak and strong nuclear interactions (gluons, for example, couple directly with each other). These theories are mostly understood in the weak-coupling regime, where perturbation theory may be applied, which contradicts the essentially strong interaction of the subnuclear force.

I am primarily interested in developing nonperturbative methods for use in quantum field theories and gauge theories. In the past I have worked on the quantum finite-element lattice method, variational perturbation theory, the delta or logarithmic expansion, and analytic perturbation theory. At present I am developing a new alternative to conventional Hermitian quantum theories, where symmetry under the combination of space and time reflection is used in place of mathematical Hermiticity to define a unitary theory. These ideas are being applied to quantum electrodynamics and quantum chromodynamics. Quantum vacuum energy phenomena (Casimir effects) are also nonperturbative in that the background reflects nontrivial topological configurations of the underlying fields. Applications range from subnuclear through nanontechnological to cosmological phenomena. Finally, I continue to have interest in developing the theory of magnetic monopoles.

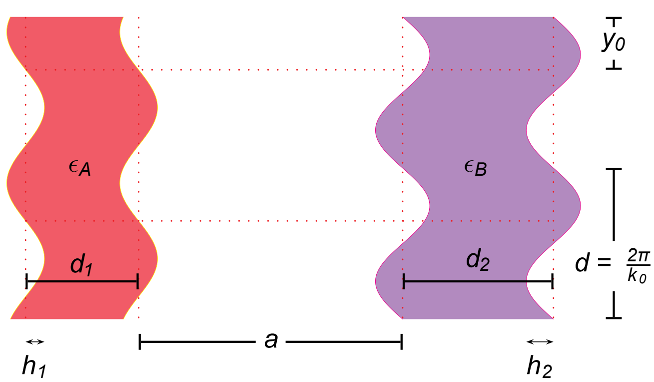
"PT-Symmetric Quantum Electrodynamics and Unitarity," K. A. Milton, E. K. Abalo, P. Parashar, N. Pourtolami, and J. Wagner, to be published in *Phil. Trans. A.* arXiv:1204.5235

"The Casimir Force: Feeling the Heat," K. A. Milton, *Nature Physics* **7**, 190-191 (2011).

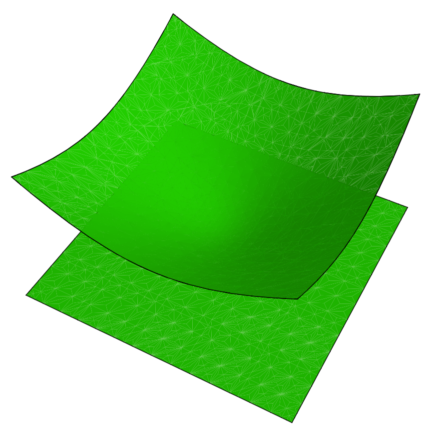
"Casimir Energies of Cylinders: Universal Function," E. K. Abalo, K. A. Milton, and L. Kaplan, *Phys. Rev. D* **82**, 125007 (2010).

"Casimir Effect for a Semitransparent Wedge and an Annular Piston," K. A. Milton, J. Wagner, and Klaus Kirsten, *Phys. Rev. D* **80**, 124028 (2009).

"Exact Results for Casimir Interactions between Dielectric Bodies: The weak-coupling or van der Waals limit," K. A. Milton, P. Parashar ,and J. Wagner, *Phys. Rev. Lett.*, **101,** 160402 (2008).



Non-contact gears. Quantum electrodynamics implies a vacuum energy between dielectric bodies. In particular, there is a lateral force between corrugated surfaces. Moving one body parallel to the other will transmit a sideways force on the second, without contact between the bodies which would result in stiction. Such a device could be used in nanomachinery.



New calculational techniques in quantum field theory allow us to compute the quantum vacuum forces between arbitrarily shaped bodies. Shown here is a hyperboloid of revolution above a plane, for which the Casimir force can be computed exactly. Previously only forces between parallel planes could be exactly evaluated.

[Patrick Skubic]

professor

B.S. 1969 South Dakota State

Ph.D. 1977 University of Michigan

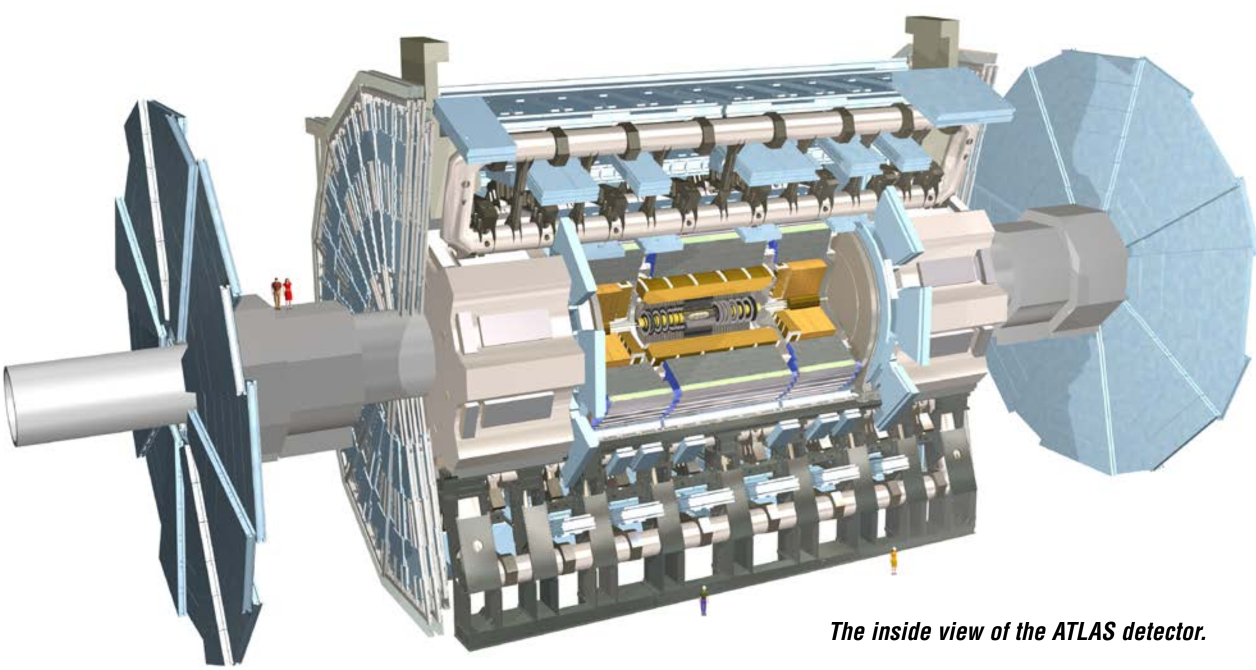
"Search for supersymmetry in pp collisions at $\sqrt{s}$ = 7 TeV in final states with missing transverse momentum and b-jets." ATLAS Collaboration, *Physics Letters B* **701**, 398 (2011).

"Top Quark Pair Production Cross-section Measurements in ATLAS in the Single Lepton+Jets Channel without b-tagging" ATLAS Collaboration, ATLAS-CONF-2011-023.

My area of research is experimental elementary particle physics. My present interest is in experiments at the energy frontier including those that use the world's highest energy accelerators to study collisions of subatomic particles such as protons. I also have a strong interest in the development of semiconductor detectors for use in high energy physics experiments, and I am currently involved in several major efforts in the continued development of these detectors.

Over the last decade I have been working within the department's high-energy group on the development and construction of silicon pixel detectors for an experiment called ATLAS. This experiment is currently taking data at the Large Hadron Collider (LHC) that is at the European particle physics laboratory CERN located in Geneva, Switzerland. It is a multipurpose detector to study collisions between protons at a center-of-mass energy of 7 TeV. A major goal of ATLAS is to discover the Higgs particle, which is thought to be responsible for the generation of the masses of other particles according to current theory. If the Higgs particle is discovered, this will open up whole new areas of study. Our group is analyzing ATLAS data and we have presented recent results on the measurement of the top-antitop quark pair production cross section and on results of searches for supersymmetry.

The pixel detectors we helped to develop are the detector elements closest to the collision point and provide the best position measurements for charged particles produced in collisions. We are also participating in hardware improvements to the existing ATLAS detector that are under construction including another layer of silicon pixel detectors that will be added during a planned shutdown starting in 2013.



The inside view of the ATLAS detector.

[Michael Strauss]

professor

David Ross Boyd Professor

B.S. 1981 Biola University

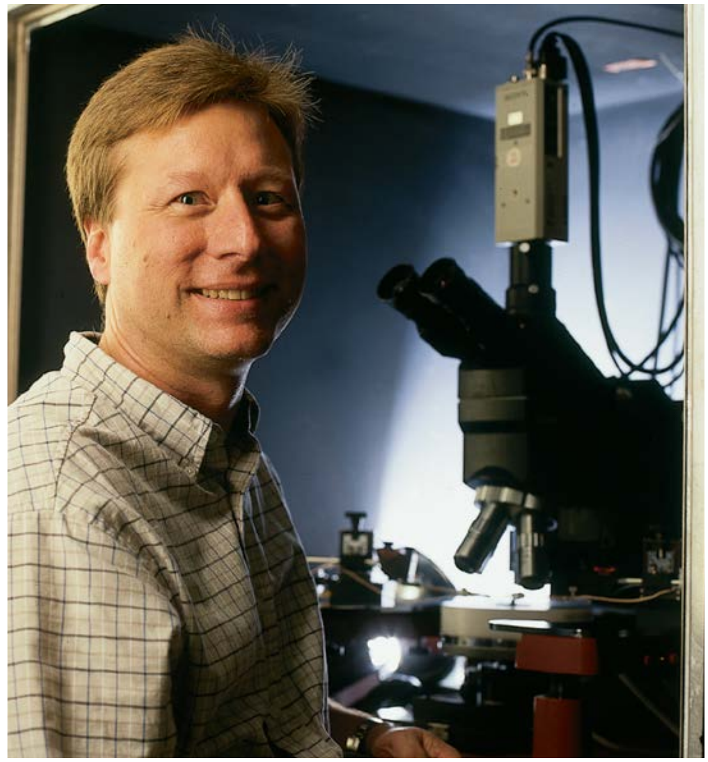
Ph.D. 1988 University of California, Los Angeles

My research is in Experimental Particle Physics. I am currently studying data from both the DØ detector using the Tevatron collider at the Fermi National Accelerator Laboratory near Chicago and the ATLAS detector using the Large Hadron Collider (LHC) at CERN laboratory near Geneva, Switzerland. Both these machines are excellent instruments for testing the predictions of the Standard Model of elementary particles and fields and to look for experimental deviations from those predictions.

At the Tevatron my recent research has focused on testing various properties of Quantum Chromodynamics (QCD), particularly the distribution of gluons within the proton.

The LHC is now the highest energy particle collider in the world and has the potential of discovering new phenomena which may extend or supersede the Standard Model. Studies indicate that answers to fundamental questions about the nature of mass, the asymmetry between matter and antimatter, and even the particles that make up the dark matter in the universe may be discovered in the near future at the LHC. Within the next few years, I will focus my research exclusively on data from the ATLAS detector.

With the end of the Tevatron run and the excellent performance of the LHC, the future potential for the discovery and observation of new and interesting phenomena in the field of elementary particles and fields looks extremely promising. It is an exciting time to be doing experimental physics in this field.



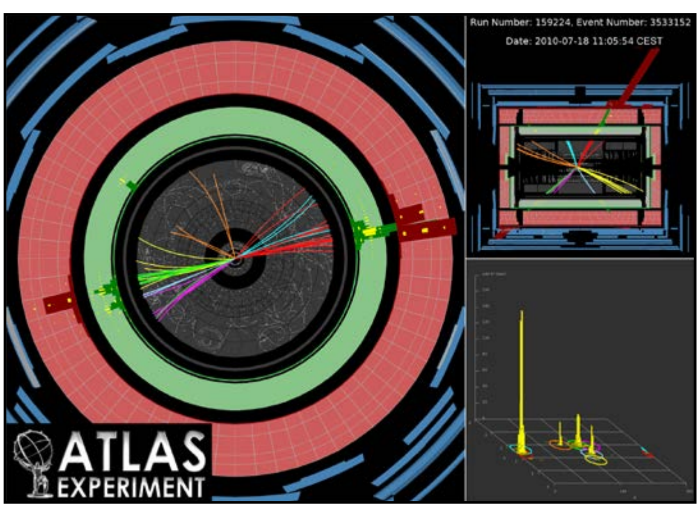
V.M. Abazov, M. Strauss,*et.al.* (DØ Collaboration) "Measurement of the dijet invariant mass cross section in ppbar collisions at $\sqrt{s}$ = 1.96 TeV," *Physics Letters B* **693**, 531 (2010).

V.M. Abazov, M. Strauss, *et al.* (DØ Collaboration) "Measurement of the inclusive jet cross section in ppbar scattering at $\sqrt{s}$ = 1.96 TeV," *Physical Review Letters* **101**, 062001 (2008).

V.M. Abazov, M. Strauss, *et al.* (DØ Collaboration) "Evidence for production of single top quarks and first direct measurements of $|V_{tb}|$," *Physical Review Letters* **98**, 181902 (2007).

V.M. Abazov, M. Strauss, *et al.* (DØ Collaboration) "Ratio of Isolated Photon Cross Sections in proton-antiproton Collisions at $\sqrt{s}$ = 630 and 1800 GeV," *Physical Review Letters* **87**, 251805 (2001).

B. Abbott, M. Strauss, *et al.* (DØ Collaboration) "Direct Measurement of the Top Quark Mass at DØ," *Physical Review* **D58**, 52001 (1998).



A computer drawing of the debris from the collision of protons in the ATLAS detector at an energy of 7 TeV in the LHC. In this event two jets of particles are seen indicating the production of quarks from the proton interactions.