Curriculum Vitae

Professor Matthew Herndon

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Education

Ph.D., Physics, University of Maryland, November 1998
Thesis topic: Search for the B_c Meson in Hadronic Z^0 Decays
Thesis adviser: Professor Hassan Jawahery

B.S., Physics, University of Texas at Austin, August 1994

Professional Employment

07/2012 to present: Professor, Department of Physics, University of Wisconsin-Madison:
Participating in the CDF and CMS experiments at the Tevatron and LHC colliders.

07/2009 to 06/2012: Associate Professor, Department of Physics, University of Wisconsin-Madison

08/2005 to 06/2009: Assistant Professor, Department of Physics, University of Wisconsin-Madison

11/98 to 08/2005: Associate Research Scientist, Department of Physics and Astronomy, Johns Hopkins University (Supervisor: Professor Bruce Barnett):
Participating in the CDF experiment at the Tevatron collider.

1/93 to 11/98: Research Assistant, Department of Physics, University of Maryland (Adviser: Professor Hassan Jawahery):
Participating in the OPAL and BaBar experiments at the LEP and PEPII colliders.

9/92-12/93: Teaching Assistant, Department of Physics, University of Maryland(Supervisor: Professor Richard Ellis)
Recitations and laboratory sessions for introductory physics courses.

1/91 to 8/92: Student Researcher, Applied Research Laboratory Austin, Texas.
Programming for naval sonar simulation.

Research Activities

CMS Muon System

Currently my group is participating in the refurbishment of the cathode strip chambers (CSC) electronics for the HL-LHC. 8 rings of chambers are being dismounted and brought to the surface where the front end readout electronics are being replaced. We are active in the extraction and refurbishment processes and also in radiation protection

and management capacities. Previously my group participated in the construction, testing, installation and commissioning of the ME4/2 ring of cathode strip chambers (CSCs) which completed the original design of the CMS muon system. We are also engaged in operation and data quality monitoring of the CSC. We are also participating in the longevity testing of the CSC chambers at the GIF radiation testing facility. These tests are aimed at understanding the long term performance of the CSC system given the expected integrated radiation doses at the HL-LHC. We participated in setting up the test chambers and DAQ system and now in running and analyzing the test data. In addition, test of new gas mixtures will be performed using this setup. I serve as Resource Manager for the CSC system managing personal and expenditures for the system as a whole.

CMS Multiboson Physics

At the CMS experiment I am participating in SM physics measurements and searches for new physics in channels involving pairs of W or Z bosons. This research program leverages my experience in tracking, muon detection, and di-boson physics at the CDF experiment. As part of this analysis program we have performed a measurements of the SM cross sections for WZ and ZZ production, measurements of differential cross sections, and searches for new physics that could manifest as anomalous tripple gauge couplings between the gauge bosons. This work has been expanded to studies of scattering typologies of WZ and ZZ pairs of massive vector bosons which allows the study of quartic gauge coupling and longitudinal vector boson scattering. This type of physics is a sensitive probe of the exact nature of electroweak symmetry breaking and whether it involves purely a standard model Higgs boson or there are new physics contributions present. Previously we produced a study of the potential of the WZ mode for the higher energies and luminosities of the next LHC run and recently we completed a publication on vector boson scattering in the WZ final state using the 13 TeV LHC data. We are currently working on vector boson scattering and vector boson polarization in the ZZ final state. I led 2012-2014 I led the Standard Model Physics Multiboson Physics Group, the CMS Standard Model HL-LHC future physics studies group, and I am Rivet analysis coordinator for the SMP group. I also supervise the extensive multiboson physics program at UW.

CDF Experiment At the CDF experiment I worked on subjects including high mass searches for the Higgs boson in decays to WW and cross section measurements of WW and WZ diboson production. This research effort resulted in the first exclusions of possible standard model Higgs masses from a hadron collider. Also I participated in searches for Bs decays to mumu and the first observation of Bs mixing. I led the CDF Higgs and B physics analysis groups. My contributions to the CDF experiment included installation and commissioning of the CDF Run 2 silicon detector and development of the silicon tracking software. I also led the CDF tracking group.

OPAL and Babar Experiments

As a graduate student at the University of Maryland I worked in the High Energy Physics group on the BaBar and OPAL experiments. For the BaBar experiment I performed a study of a precision Time-Of-Flight system using scintillation counters and Fine Mesh Photomultiplier Tubes. At OPAL my activities included work on the Hadron Calorimeter hardware and simulation software. My thesis analysis was a search for the

Bc meson using decay modes involving the J/Psi.

Leadership Activities

Resource manager for the CMS CSC muon detector system 2019-present// As resource manager I track personal and expenditures for the CSC system across the various US and Russian groups involved in the project.

Rivet Coordinator For the CMS Standard Group 2017-present
The Rivet framework allows physicist using standard MC formats to apply the experimental selection to a process and compare cross section results with their model. This allows easy comparison between experiments and between experiments an d theory predictions.

Coordinator CMS Standard Model HL-LHC Physics Studies Group 2014-2017
This group is charged with developing the physics case for to motivate the High Luminosity LHC and associated CMS upgrades based on Standard Model physics

Co-convener CMS Standard Model Physics Multiboson Physics Group 2012-2014.
As convener of the CMS multiboson physics group I supervised physics involving the production of two or more vector bosons.

Programming Reconstruction Software for Large Computing Projects
During the spring of 2014 I was on research leave to Fermilab where I was the lead developer a workshop style course on developing reconstruction software in large computing projects. The course was taught in August 2014.

Co-convener CDF Higgs Discovery Group 2007-2008
The Higgs group was one of six major research groups in the CDF collaboration. This research group was formed in 2007 to meet the challenge of searching for the Higgs boson at CDF and I was appointed one of its two inaugural conveners.

Co-convener CDF B Physics Group 2006-2007
As B group convener I directed the CDF B and Charm physics program. The B physics group was conducting more than 50 physics analyses on a diverse number of subjects.

Co-convener of the CDF J/Psi Physics Subgroup 2005
As convener of the J/Psi subgroup I supervised low transverse momentum di-lepton physics including subjects from rare decay searches to mass, lifetime and branching ratio measurements of b hadrons.

Co-convener of the CDF Tracking Group 2003-2005
As tracking group convener I directed the tracking software development for offline data processing and high-level trigger at CDF. During my convenership the final version of the tracking software used for all Run 2 CDF data reconstruction was established.

CDF Silicon Commissioning and Power Supplies
Leadership of the group established to study the silicon data during the CDF commissioning run. Manager of the silicon vertex detector power supply project.

Students

Susmita Mondal: University of Wisconsin, started 2020, research topic: ZZ vector boson polarization.

He He: Graduate Student: University of Wisconsin, started 2018, research topic: ZZ vector boson scattering. Service: CSC Muon system electronics testing.

Stephen Trembath-Reichert: Graduate Student: University of Wisconsin, started 2017, research topic: ZV (with hadronic V, W or Z, decay) scattering and anomalous quartic gauge coupling at CMS. Service: CSC Muon system monitoring and electronics refurbishment.

Keegan Downham, Undergraduate Student, thesis topic, Survey of sensitivity to vector boson scattering of in all massive di-boson final states. Accepted for graduate school at UCSB. Former Students:

Kenneth Long: Graduate Student: University of Wisconsin, started 2013, research topic: WZ scattering and anomalous quartic gauge coupling at CMS. Service: Muon system long term radiation tests. Muon system monitoring. Graduated: Now a CERN fellow.

William Parker - Graduate Student, thesis topic: Search for Higgs production and decay to two W bosons in association with two jets and measurement WW cross section. Service: Monitoring of silicon tracking software performance. Now a postdoc at The University of Maryland 2010-2014

Jeff Klukas - Graduate Student, thesis topic: Search for W-Prime and technicolor particle production in the WZ decay mode at CMS and measurement of the WZ cross section. Service: monitoring, validation and development of the CMS muon high level trigger, 2007-2012, Graduated

Jason Nett - Graduate Student, thesis topic: Search for associated production of the standard model Higgs boson in the channel VH to VWW at CDF and measurement of the WZ cross section. Service: development of forward muon triggers, 2006-2010. Now a postdoctoral research at Texas A&M University

Brendt Christensen, Joseph D Kowalski, Rich Ormiston, Undergraduate Students, thesis topic: W+W+ production at CMS. 2011-2013. Brendt Christensen graduated 2013, will attend graduate school at University of Illinois Champaign Urbana

Ryne Carbone - Undergraduate Student, thesis topic: Higgs and Z to tautau decays at CMS. 2011-2012. Graduated 2012. Graduated Columbia 2017

David Sperka - Undergraduate Student, thesis topic: Search for Flavor Changing Neutral Current Decay of Bs mesons to two muons at CDF, 2008-2009. Service: validation of CDF L00 data. Graduated 2009. Graduated Boston University. Postdoc at the University of Florida. Now Research Professor Boston University.

Postdoctoral Researchers

Dr. Isabelle De-Bryun - Involved in the CMS muon system electronics refurbishment working on chamber extraction and project management. CSC Radiation Protection Officer and CSC electronics upgrade leader. Working on new physics in trackless jets and multi-boson physics. Former Postdoctoral Researchers:

Dr. Senka Djuric - Involved in CMS muon system construction and commissioning, muon system long term radiation tests, muon system detector performance monitoring, muon DOC system expert, and multi gauge boson physics. Currently searching for anomalous triple gauge coupling in WZ and ZZ production and measuring differential

distributions in ZZ production. Served as convener of the CMS SMP multiboson physics group and Muon system detector performance group (DPG) coordinator.
Dr. Jennifer Pursley - Involved in the search for Standard Model Higgs boson in the two W boson decay channel where she led that subgroup, measurement of the Standard Model WW boson production cross section, measurement of the top production cross section, and observation of excited b flavored hadrons Bs** and SigmaB. Served as CDF operations manager. 2008-2010, Now Research Scientist at Harvard Medical School.

Professional Activities

Teaching

Spring 2020 - Physics 202 - General Physics II
Fall 2019- Physics 202 - General Physics II
Spring 2019 - Physics 202 - General Physics II
Fall 2018 - Physics 249 - A Modern Introduction to Physics III: Quantum Mechanics
Spring 2018 - Physics 104 - General Physics II
Fall 2017 - Physics 103 - General Physics I
Spring 2017 - Physics 202 - General Physics II
Fall 2016 - Physics 201 - General Physics I
Spring 2016 - Physics 248 - A Modern Introduction to Physics II
Fall 2015 - Physics 241, Introduction to Modern Physics
Spring 2015 - Physics 103, General Physics II
Fall 2014 - Physics 241, Introduction to Modern Physics
Fall 2013 - Physics 104, General Physics II
Spring 2013 - Physics 103, General Physics I
Fall 2012 - Physics 249, A Modern Introduction to Physics III: Quantum Mechanics
Spring 2012 - Physics 535, Introduction to Particle Physics
Fall 2011 - Physics 202, General Physics II
Spring 2011 - Physics 535, Introduction to Particle Physics
Fall 2010 - Physics 103, General Physics I
Spring 2010 - Physics 535, Introduction to Particle Physics
Fall 2009 - Physics 103, General Physics I
Spring 2009 - Physics 104, General Physics II
Fall 2008 - Physics 103, General Physics I
Spring 2008 - Physics 103, General Physics I
Fall 2007 - Physics 535, Introduction to Particle Physics
Spring 2007 - Physics 103, General Physics I
Fall 2006 - Physics 107, Ideas of Modern Physics
Spring 2006 - Physics 104, General Physics II
Fall 2005 - Physics 107, Ideas of Modern Physics

Workshops

Proposed, designed and taught the FNAL Software School on Programming Reconstruction Software for Large Computing Projects

Multiboson Interactions Workshop: Organizing Committee 2013-2017, Chair Organizing Committee 2016. Workshop held in Madison in 2016.

Departmental

Admissions Committee 2018-present
Faculty Senator 2016-present
Faculty Senator Alternate 2014-2015
Physics Learning Center Oversite 2014-2016
Diversity Committee, Chair 2010-2014, 2017
Preliminary Exam Committee, 2005-2008, Chair 2009-2011, 2012-2113, 2016-present
Promotions: 2012-2016,2019-present
Salary: 2012-2014,2019-present
Research Capital: 2011-2012, Chair 2011-2012
Outreach and Museum, 2011-2012
Physics Counsel, 2009-2011, 2017
Qualifying Exam Committee, 2006-2009, 2014-present
Graduate Program Committee, 2007-2009.
Web Committee, 2008-2009.
Colloquium Committee, 2006-2007.

Other Professional Activities

CSC Resource Manager 2019-present
SMP Rivet coordinator 2017-present
VBSCan US representative 2017-present
CDF Editorial board member 2014-present
CMS SMP HL-LHC Physics Coordinator 2014-2017
Co-convener CMS Standard Model Physics
Multiboson Subgroup 2012-2014
Co-convener CDF Higgs Discovery Group 2007-2009
Co-convener CDF B Physics Group 2006-2007
Co-convener of the CDF J/Psi Physics Subgroup 2005
Co-convener of the CDF Tracking Group 2003-2005
Convener CDF Silicon Tracking Group 2001-2002
Reviewer for the Journal of High Energy Physics (JHEP)
Reviewer for the European Physical Journal C (EPJC)
Reviewer for Nuclear Inst. and Methods in Physics Research (NIM)
Organizing Wisconsin High Energy Physics Seminar
Organizer "Multiboson Interactions Workshop", 2014 BNL, 2015 DESY, 2016 Madison (Chair organizing committee), 2017 Karlsruhe
Organizer "Anomalous Quartic Gauge Couplings", 2013, Dresden, Germany.
Organizer "Higgs Physics" session at the DPF APS July Meeting, 2009, Detroit, Michigan.
Organizer "Heavy Flavor Physics" session at the Hadron Collider Physics Symposium, 2007, Elba, Italy.
Convener "B Physics" session at the American Physical Society April Meeting, 2007, Jacksonville, Florida.

Organizer "Heavy Flavor Physics and Search for New Particles" session at the Particles and Nuclei International Conference, 2005, Santa-Fe, New Mexico.

Outreach Visits for elementary students to introduce them to physics and astronomy, Verona School district, 2016,2018
Interviewed by New Scientist on Vector Boson Scattering and Quartic Gauge Boson Coupling, 2014
Interviewed by WORT on the LHC, 2011
Lectures for high school students on the Tevatron and LHC Higgs search at Edgewood college 2011

Honors

Vilas Associate 2012-2013

Selected Publications

Review Articles

G. Bernardi, M. Herndon,, "Standard model Higgs boson searches through the 125 GeV discovery,"
Rev. Mod. Phys. **86**, 479 (2014).
This invited review article presents a review of Higgs boson searches at Hadron Colliders including the Tevatron and the LHC through the initial discovery of a new boson with mass 125 GeV

M. Herndon,, "Higgs Boson Searches at the Tevatron,"
Ann. Rev. Nucl. Part. Sci. **61**, (2011).
This invited review article presents a review of Higgs boson searches including the status of Tevatron and previous Higgs boson searches and the prospects of the LHC experiments.

Primary Author

Papers on which I and members of my research group were primary authors with substantial contributions to the research.

A. M. Sirunyan *et al.* [CMS Collaboration], "Measurement of electroweak WZ boson production and search for new physics in WZ + two jets events in pp collisions at $\sqrt{s} = 13$ TeV Authors: CMS Collaboration,"
Phys. Letters B **795**, 281 (2019), arXiv:1901.04060 [hep-ex].
Measurement of electroweak WZ boson production and search for new physics. This analysis was performed by my student, Kenneth Long, for his Ph.D. thesis. In addition Dr. Senka Duric contributed to the anomalous quartic gauge coupling constraints.

A. M. Sirunyan *et al.* [CMS Collaboration], "Measurements of the pp→WZ inclusive and differential production cross section and constraints on charged anomalous triple gauge couplings at $\sqrt{s} = 13$ TeV,"
JHEP **1904** (2019) 122, arXiv:1901.03428 [hep-ex].
Measurement of WZ boson production. Dr. Senka Duric contributed to the anomalous triple gauge coupling constraints.

A. Albert *et al.* [CMS Collaboration], "Standard Model Physics at the HL-LHC and HE-LHC,"
CERN-LPCC-2018-03
D. Teague contributed a study of EWK WZ scattering with advise from A. Savin, K. Long and myself.

A. M. Sirunyan *et al.* [CMS Collaboration], "Performance of the CMS muon detector and muon reconstruction with proton-proton collisions at $\sqrt{s} = 13$ TeV,"
JINST **13**, no. 06, P06015 (2018), arXiv: 1804.04528 [hep-ex].
Paper documenting the performance of the CMS muon system. The measurements of local efficiencies of hits and segments were performed by my postdoc, Senka Duric, using code developed by Dr. Duric and myself.

V. Khachatryan *et al.* [CMS Collaboration], "Measurements of the pp to ZZ production cross section and the Z to 4l branching fraction, and constraints on anomalous triple

gauge couplings at sqrt(s) = 13 TeV"
Eur. Phys. J. **C 78**, 165 (2018), arXiv: 1709.08601 [hep-ex].
Paper documenting measurements of the ZZ cross section at 13 TeV and including differential cross section and anomalous triple couplings(aTGC) involving neutral gauge bosons during the LHC Run 2. Limits on aTGCs were performed by my postdoc, Senka Duric. Comparisons to theory cross sections were prepared by my student, Kenneth Long.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the WZ production cross section in pp collisions at sqrts = 7 and 8 TeV and search for anomalous triple gauge couplings at sqrts = 8 TeV"
Eur. Phys. J. **C 77**, 236(2017), arXiv: 1609.05721 [hep-ex].
Paper documenting measurements of the WZ cross section at 7 and 8 TeV and including differential cross section and anomalous triple couplings(aTGC) involving charged gauge bosons during the LHC Run 1. WZ cross section measurements at 7 TeV were performed by my student, Jeff Klukas, and comprised part of his thesis research. Limits on aTGCs were performed by my postdoc, Senka Duric. Comparisons to theory cross sections were prepared by my student, Kenneth Long.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the WZ production cross section in pp collisions at sqrt(s) = 13 TeV"
Phys. Lett. B **766**, 268 (2016), arXiv: 1607.06943 [hep-ex].
Paper documenting the first measurement of the WZ cross section in 13 TeV pp collisions. This measurement was worked on by my Student Kenneth Long concentrating on understanding of experimental and theory total and fiducial region cross sections.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the ZZ production cross section and $Z \to l^+l^-l'^+l'^-$ branching fraction in pp collisions at $\sqrt{s} = 13$ TeV"
Phys. Lett. B, arXiv: 1607.08834 [hep-ex].
Paper documenting the first measurement of the ZZ cross section in 13 TeV pp collisions. This measurement was worked on by my Student Kenneth Long.

V. Khachatryan *et al.* [CMS Collaboration], "Measurements of the ZZ production cross sections in the 2 l 2 nu channel in proton-proton collisions at sqrt(s) = 7 and 8 TeV and combined constraints on triple gauge couplings"
Eur. Phys. J. **C 75**, 511(2015), arXiv:1503.05457 [hep-ex].
European Physics Journal paper documenting a measurement of the ZZ cross section and setting the worlds most stringent limits on anomalous triple couplings(aTGC) involving neutral gauge bosons during the LHC Run 1. This measurement and combination of aTGC parameters was performed by my postdoc Senka Duric.

T. Aaltonen *et al.* [CDF Collaboration], "Measurement of the production and differential cross sections of W^+W^- bosons in association with jets in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV"
Phys. Rev. **D 91**, 111101 (2015), arXiv:1505.00801 [hep-ex].
PRD documenting a differential measurement of the Tevatron WW cross section vs. jet multiplicity and transverse energy. This measurement is the first of it's kind in a heavy diboson state. The work comprised part of the thesis of and Dr. William Parker.

V. Khachatryan *et al.* [CMS Collaboration], "Measurements of the ZZ production cross sections in the $2\ell 2\nu$ channel in proton-proton collisions at $\sqrt{s} = 7$ and 8 TeV and combined constraints on triple gauge couplings,"
Eur. Phys. J. **C 75**, no. 10, 511 (2015), arXiv:1503.05467 [hep-ex].
EPJC article on ZZ production and aTGCs. Limits on aTGC from this analysis and combined limits from all CMS ZZ analysis are presented based on work by my postdoc Dr. Senka Duric.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of the $pp \to ZZ$ production cross section and constraints on anomalous triple gauge couplings in four-lepton final states at $\sqrt{s}$ =8 TeV," *Phys. Lett. B* **740**, 250 (2015), arXiv:1406.0113 [hep-ex].
PLB article on ZZ production and aTGC. Limits on aTGC and differential distribution of ZZ production are presented based on work by my postoc Dr. Senka Duric.

T. Aaltonen *et al.* [CDF Collaboration], "Searches for the Higgs boson decaying to W+ W- to lnu lnubar with the CDF II detector"
Phys. Rev. **D 88**, 052012 (2013), arXiv:1306.0023 [hep-ex].
PRD documenting the combination of CDF H to WW search including H to WW with 2jets and VH to VWW trilepton search topologies developed by my students Dr. Jason Nett and Dr. William Parker.

T. Aaltonen *et al.* [CDF and D0 Collaborations], "Higgs Boson Studies at the Tevatron,"
Phys. Rev. **D 88**, 052014 (2013), arXiv:1303.6346 [hep-ex].
PRD documenting the combination of CDF and D0 Higgs searches including results in the H to WW with 2jets and VH to VWW trilepton search topologies developed by my students Dr. Jason Nett and Dr. William Parker.

T. Aaltonen *et al.* [CDF Collaboration], "Combination of searches for the Higgs boson using the full CDF data set,"
Phys. Rev. **D 88**, 052013 (2013), arXiv:1301.6668 [hep-ex].
PRD documenting the combination of CDF Higgs searches including results in the H to WW with 2jets and VH to VWW trilepton search topologies developed by my students Dr. Jason Nett and Dr. William Parker.

T. Aaltonen *et al.* [CDF Collaboration], "Search for $B_s \to \mu^+\mu^-$ and $B_d \to \mu^+\mu^-$ decays with the full CDF Run II data set,"
Phys. Rev. **D 87**, 072003 (2013), arXiv:1301.7048 [hep-ex]. PRD documenting the complete Bs to mumu analysis. I participate in this analysis producing silicon tracking efficiencies, muon identification tools, and discriminant design. I have advised undergraduate David Sperka and graduate student Walter Hopkins who wrote thesis's on this topic.

T Aaltonen *et al.* "Operational Experience, Improvements, and Performance of the CDF Run II Silicon Vertex Detector,"
Nucl. Instrum. Meth., A 729 (2013) 153-181, arXiv:1301.3180 [physics-instr]
Responsible for power supply and cabling purchase, installation, commissioning and operation. Responsible for silicon system performance monitoring using offline data.

S. Chatrchyan *et al.* [CMS Collaboration], "Search for exotic particles decaying to WZ in pp collisions at sqrt(s)=7 TeV,"
Phys. Rev. Lett. **109**, 141801 (2012), arXiv:1206.0433 [hep-ex].
I am a primary author on the search for exotic particles decaying to a WZ boson pair at CMS. This work was my student Jeff Klukas thesis project.

T. Aaltonen *et al.* [CDF Collaboration], "Measurement of the WZ Cross Section and Triple Gauge Couplings in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV,"
Phys. Rev. **D 86**, 031104 (2012), arXiv:1202.6629 [hep-ex].
I am a primary author on the measurement of the WZ cross section at CDF. This work was part of my student Jason Nett's thesis project.

The CDF Collaboration, T. Aaltonen, et al., "Search for Bs to mumu and Bd to mumu Decays with CDF II,"
Phys. Rev. Lett. **107**, 191801 (2011), arXiv:1107.2304 [hep-ex].
I am a primary author on the search for Bs mesons decaying to two muons. This paper presented the first indication of a signal in this rare decay process. A signal with the branching ratio measured in this result is clear evidence for physics beyond the standard model. The improvements to the sensitivity of this analysis were developed by my undergraduate student, David Sperka, and myself.

The CDF and D0 Collaborations, T. Aaltonen, et al., "Combination of Tevatron searches for the standard model Higgs boson in the W^+W^- decay mode,"
Phys. Rev. Lett. **104**, 061802 (2010), arXiv:1001.4162 [hep-ex].
The combination of the improved CDF high mass Higgs search with the results from the D0 experiment led to the first published exclusion of possible Higgs mass from a hadron collider. This result was featured on the front cover of PRL and highlighted in a special guest article explaining the importance of the result.

The CDF Collaboration, T. Aaltonen, et al., "Inclusive Search for Standard Model Higgs Boson Production in the WW Decay Channel using the CDF II Detector,"
Phys. Rev. Lett. **104**, 061803 (2010), arXiv:1001.4468 [hep-ex].
I am a primary author of the inclusive search for the Higgs boson decaying to two W bosons. This analysis increased the sensitivity of the CDF Higgs boson search by considering all production modes of the Higgs boson. The alternative production methods of associated production and vector boson fusion primarily contribute to events with multiple jets or additional leptons. The design of this improved analysis, which had 50% additional signal acceptance, was the work of myself, my postdoc, Jenifer Pursley, and my graduate student, Jason Nett.

The CDF Collaboration, T. Aaltonen, et al., "Measurement of the W^+W^- Production Cross Section and Search for Anomalous $WW\gamma$ and WWZ Couplings in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV,"
Phys. Rev. Lett. **104**, 201801 (2010), arXiv:0912.4500 [hep-ex].
The same analysis designed for the Higgs boson search was used to measure the cross section of WW production and search for new physics through anomalous $WW\gamma$ and WWZ couplings.

The CDF Collaboration, T. Aaltonen, et al., "Search for a Higgs Boson Decaying to Two W Bosons at CDF,"
Phys. Rev. Lett. **102**, 021802 (2009), arXiv:0809.3930 [hep-ex].

In addition to supervising all analysis performed in the Higgs Discovery Group during the time period 2007-2008, I am a primary author on the search for the Higgs boson decaying to two W bosons. I developed a methodology for accessing systematic uncertainty on our understanding of the production of Heavy particles with jets in processes initiated by gluons inside the proton. This allowed us to expand this Higgs search to events including two W bosons and one additional jet substantially increasing the sensitivity of this search. In collaboration with my postdoctoral researcher, Jennifer Pursley this program of research has been expanded to also include events with two or more jets. These improvements have led to the first exclusion of a range of possible Higgs masses since the final analysis of the LEP collaboration.

The CDF Collaboration, T. Aaltonen, et al., "Search for Bs to mumu and Bd to mumu Decays with 2fb-1 of ppbar Collisions," *Phys. Rev. Lett.* **100**, 101802 (2008), arXiv:hep-ex/0712.1708.

I am a primary author on the search for Bs mesons decaying to two muons. Based on my expertise in tracking and silicon detectors I developed a selection for muons with silicon detector position information, or hits, that is high efficiency while maintaining a low rate of mis-measurements that can lead in inaccurate lifetime measurements. The accurate measurement of the long lifetime of Bs mesons is the key method of separating the signal from background. In addition, I developed a multivariate discriminant for muon identification that further improves selection efficiency and rejection of background events. This analysis has resulted in the most stringent bound on the rate of Bs meson decay to two muons and severely restricts many new models of physics.

The CDF Collaboration, D. Abulencia et al., "Observation of Bs Oscillations," *Phys. Rev. Lett.* **97**, 242003 (2006), arXiv:0609040 [hep-ex].

In addition, to supervising all analysis performed in the B physics group during the time period 2005-2006, I was also a primary author on the analysis that observed the process of oscillation in Bs mesons which converts them from their mater to antimatter states. The oscillation process of the Bs meson is extremely fast and the tens of micron level accuracy of the CDF silicon detector is necessary to observe the process. I implemented the use of the innermost layer of silicon of the CDF silicon detector for this analysis, which substantially enhances the resolution for Bs meson lifetime measurements making is possible to observe the oscillation process as a function of time. The use of the innermost silicon layer was the single most important factor in achieving the sensitivity necessary for the observation of Bs oscillations and without the enhanced sensitivity this analysis would not have even achieved the statistical sensitivity necessary for the lesser claim of evidence.

The CDF Collaboration, D. Abulencia et al., "Measurement of the Bs Oscillation Frequency," *Phys. Rev. Lett.* **97**, 062003 (2006), arXiv:hep-ex/0606027.

I was a primary author on this paper focusing on the integration of the innermost silicon layer into the measurement and developing a model of the lifetime resolution when using the innermost silicon layer.

The CDF Collaboration, D. Acosta et al., "Search for Bs to mumu and Bd to mumu Decays in ppbar Collisions with CDF II," *Phys. Rev. Lett.* **95**, 221805 (2005), arXiv:hep-ex/0508036.

I pioneered the use of the innermost silicon layer in this analysis. The innermost silicon layer had not been used in any previous analysis due to substantial noise problems in the data from the detector. I assisted in developing a method to suppress the noise, authored code to find and add position data from the detector to precisely measure the trajectories of charged particles, calibrated the detector for optimum physics performance, and characterized the resolution of the detector. Following this analysis the innermost silicon layer is now used in all CDF analysis.

C. Hays, M. Herndon *et al.*, "Inside-out Tracking at CDF," *Nucl. Instrum. Meth. A* **538**, 249 (2005).
I was a primary author of a new tracking algorithm to identify charged particle trajectories over a larger solid angle of the detector. This new algorithm, which primarily uses the silicon detector rather than the drift chamber, is now used in all CDF analysis.

The CDF Collaboration, D. Acosta et al., "Search for Bs to mumu and Bd to mumu Decays in ppbar Collisions at sqrt(s) = 1.96 TeV," *Phys. Rev. Lett.* **93**, 032001 (2004), arXiv:hep-ex/0403032.
I was a primary author on the first search for the decay of a Bs meson to two muons in CDF Run 2 involved in all aspects of the analysis. This paper was the forth paper published in Run 2 from CDF.

Thesis: M. Herndon, "Search for the Bc Meson in Hadronic Z Decays using the OPAL detector at LEP," UMI-99-26738(1999).
My thesis analysis was a search for the heaviest possible ground state mixed quark meson known as the Bc meson. I developed and performed all aspects of the analysis independently.

The OPAL Collaboration, K. Ackerstaff et al., "Search for the Bc Meson in Hadronic Z Decays," *Phys. Letters B* **420**, 157 (1998), arXiv:hep-ex/980126.
Letter based on my thesis analysis.

M. Foucher, M. Herndon and H. Jawahery, "A Study of the Timing Characteristics of Scintillator Counters With Fine Mesh Photomultiplier Tubes," *Nucl. Instr. & Meth.* **A 374**, 57 (1996).
I was the primary of this paper on the construction of the Time of Flight detector. I constructed the apparatus, assembled the data acquisition system and analyzed the data.

Contributing Author

Papers on which I or my group members contributed physics or technical studies and expertise essential to the physics results.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of differential cross sections for Z boson pair production in association with jets at $\sqrt{(}s) = 8$ and 13 TeV"
Phys. Letters B **789**, 19 (2019), arXiv: 1806.11073 [hep-ex].
Paper documenting measurements of ZZ events with jets. Nate Woods provided a cross check analysis. Kenneth Long provided MC support.

C.F. Anders *et al.* [VBSCan COST Action network], "Vector boson scattering: Recent experimental and theory developments"

VBSCan-PUB-01-17 arXiv: 1801.04203
VBSCan Split 2017 Workshop Summary. Contributed to experimental VBS results section.

V. Khachatryan *et al.* [CMS Collaboration], "Measurement of vector boson scattering and constraints on anomalous quartic couplings from events with four leptons and two jets in proton-proton collisions at sqrt(s) = 13 TeV"
Phys. Letters B **774**, 682 (2017), arXiv: 1708.02812 [hep-ex].
Paper documenting a search for of vector boson scattering in ZZ. Nate Woods provided a cross check analysis. Kenneth Long provided MC support. I provided advising on the topic of constraints on anomalous quartic couplings.

The CMS Collaboration, S. Chatrchyan, et al., "Measurement of the production cross section for a W boson and two b jets in pp collisions at sqrt(s) = 7 TeV,"
Phys. Lett. B **735** (2014) 204, arXiv:1312.6608 [hep-ex].
Collaborated with UW CMS postdocs Maria Capeda and students on this analysis of W boson and associated heavy flavor jet production.

The CDF Collaboration, T. Aaltonen et al., "Measurement of Resonance Parameters of Orbitally Excited Narrow B0 Mesons," *Phys. Rev. Lett.* **102**, 102003 (2007), arXiv:hep-ex/0809.5007.
I developed an improved selection for finding very low momentum particles useful for finding excited B hadrons. This work was used in searches for the Sigmab baryon and excited states of the B0 meson. I also provided supervision for the graduate student thesis of Jennifer Pursley.

The CDF Collaboration, T. Aaltonen et al., "First Observation of Heavy Baryons Sigmab and Sigmab-," *Phys. Rev. Lett.* **99**, 202001 (2007), arXiv:hep-ex/0706.3868.
See previous.

The CDF Collaboration, D. Abulencia et al., " First Measurement of the Ratio of Central-Electron to Forward-Electron W Partial Cross Sections in ppbar Collisions at sqrt(s) =1.96 TeV," *Phys. Rev. Lett.* **98**, 251801 (2007), arXiv:hep-ex/0702037.
The new tracking algorithm I designed which primarily used the silicon detector rather than the drift chamber was first used in this analysis, which expanded the solid angle over with the W boson production cross section is measured.

The CDF Collaboration, D. Abulencia et al., "Measurement of sigma(Lambdab)/ sigma(B0) x BR(Lambdab to Lambda pi-) / BR(B0 to D+pi-) in ppbar Collisions at sqrt(s) = 1.96 TeV," *Phys. Rev. Lett.* **98**, 122002 (2007), arXiv:hep-ex/0601003.
I developed a method for measuring the trigger efficiency of protons in the CDF drift chamber. Protons have significantly different ionization rates in a gas compared to other particles, which effect the efficiency of detecting them. This method is used in several analyses involving B baryons that decay into protons and other particles.

The CDF Collaboration, D. Acosta et al., "Measurement of the J/Psi Meson and b-Hadron Production Cross Sections in ppbar Collisions at sqrt(s) = 1.96 TeV," *Phys. Rev. D* **71**, 032001 (2005), arXiv:hep-ex/0412071.
I developed a stringent selection for adding silicon detector position information to improve the position resolution of charged particles. I also characterized the performance in terms of efficiency and resolution for the silicon detector. This

work was critical for this measurement of the lifetime of B hadrons in decay channels involving J/Psi mesons and is used in all subsequent analysis that measure B hadron lifetimes.

The CDF Collaboration, D. Abulencia et al., "Measurement of the ttbar Production Cross Section in ppbar Collisions at sqrt(s) = 1.96 TeV using Dilepton Events," *Phys. Rev. Lett.* **93**, 142001 (2004), arXiv:hep-ex/0404036.
I developed a method to measure the efficiency of finding high momentum tracks in the CDF drift chamber. This technique was first applied in the measurement of the top production cross-section in decays involving two charged leptons and in all subsequent cross section measurements using charged leptons.

The CDF Collaboration, D. Acosta et al., "Measurement of Prompt Charm Meson Production Cross Sections in p anti-p Collisions at s**(1/2) = 1.96 TeV," *Phys. Rev. Lett.* **91**, 241804 (2003), arXiv:hep-ex/0307080.
I developed a method for measuring the efficiency of the CDF drift chamber to detect low momentum charged particles. This method was used in all subsequent absolute cross section or branching ratio measurements involving B or charm hadrons.

The OPAL Collaboration, K. Ackerstaff et al., "Measurement of the W Mass and Width in e+e- Collisions at sqrt(s) = 183 GeV," *Phys. Letters B* **453**, 138 (1999), arXiv:hep-ex/9901025.
I adapted a seed based jet finding algorithm for finding jets in the OPAL detector. I also designed a framework for comparing the performance of all jet finding algorithms which was used to identify the best jet finding algorithm in terms of jet energy resolution and accuracy. This work was also used in subsequent measurements of the W boson mass.

The OPAL Collaboration, K. Ackerstaff et al., "Measurement of the W Boson Mass and W+W- Production and Decay Properties in e+e- Collisions at sqrt(s) = 172 GeV," *Eur. Phys. J.* **C1**, 395 (1998), arXiv:hep-ex/9709006.

The OPAL Collaboration, K. Ackerstaff et al., "Measurement of the Mass of the W Boson in e+e- Collisions at sqrt(s) = 161 GeV," *Phys. Letters B* **389**, 416 (1996).

A full publication list is available at www.hep.wisc.edu/˜herndon/mfh_cv_pub.pdf

Conference Talks

Invited Plenary Talks

"Electroweak Results from CMS," Plenary talk at the LISHEP International Conference, Rio de Jeneiro, Brazil, March 17-24, 2013.

"B Physics at the Tevatron," Plenary talk at the 10-25 Years of DØ France, Paris, France, October 13-14, 2008.

"Searches for the Higgs Boson," Plenary talk at the 34th International Conference of High Energy Physics, Philadelphia, Pennsylvania, July 29-August 5, 2008.

"Flavor Physics and Dark Matter," Plenary talk at the Dark Side of the Universe, Minneapolis, Minnesota, June 5-10, 2007.

"B Physics at the Tevatron," Plenary talk at the American Physical Society April Meeting, Jacksonville, Florida, April 14-17, 2007.

"B Physics at CDF," Plenary talk at the XVII Les Recontres de Physique de la VAllee d'Aoste, La Thuille, Italy, March 9-15, 2003.

Contributed Talks

"Searches for New Physics in the Flavor Sector at the Tevatron," DIS 2005 XIII International Workshop on Deep Inelastic Scattering, Madison, Wisconsin, April 27 - May, 2005.

"Bs(d) to mumu and Direct Searches," CKM 2005, Workshop on the Unitarity Triangle, B, San Diego, California, March 15-18, 2005.

"Searches for FCNC Decays Bs(d)," 32nd International Conference on High Energy Physics, Beijing, China, August 16-22, 2004.

"New B Physics Results from CDF," The Tevatron Connection, Batavia, IL, August 9-10, 2004.

"Tracking at CDF," Computing in High Energy and Nuclear Physics, La Jolla, California, March 24-28, 2003.

"Search for the Bc Meson in Hadronic Z Decays," 1998 Joint American Physical Society and American Association of Physics Teachers Meeting, Columbus, Ohio, April 18-21, 1998.

"Measurements of the Bs and Lambdab Lifetimes," 1998 Joint American Physical Society and American Association of Physics Teachers Meeting, Columbus, Ohio, April 18-21, 1998.

Workshops

"Multiboson Production Cross Sections at the LHC," Multibosons At The Energy Frontier, Fermilab, Batavia, IL, 2019".

"BSM interpretation of "Standard Model" measurements in CMS," Reinterpretation 2017: (Re)interpreting LHC new physics search results: tools and methods, Batavia, IL, 2017".

"Anomalous Coupling and New Physics in Multibosons," Experimental Challenges of the LHC Run II, KITP, University of California Santa Barbara, 2016.

"New physics in Vector Boson Scattering," Higgs Effective Theory 2015, University of Chicago, Illinois, November, 2015.

"Standard Model Results from CMS," SEARCH 2013, SUSY, Exotics and Reaction to Confronting the Higgs, Stony Brook University, Long Island, August, 2013

"CMS overview of gauge coupling measurements at 8 TeV and plans for 13 TeV," LPC Workshop on Gauge Boson Couplings Fermi National Accelerator Laboratory, Illinois, August, 2013

"High Mass Higgs at the Tevatron," Higgs Days 2012, Santander, Spain, September, 2012

"High Mass Higgs at the Tevatron," Higgs Days 2010, Santander, Spain, October, 2010

"Standard Model Higgs Searches at CDF," Higgs Days 2009, Santander, Spain, September, 2009

"Searches for the Standard Model Higgs Boson," Collider Physics 2009, Argonne National Laboratory, Illinois, May, 2009

"Searches for the Standard Model Higgs Boson," LoopFest VIII 2009, Madison, Wisconsin, May, 2009

"Searches for the Standard Model Higgs Boson," Zurich Workshop on Higgs Boson Phenomenology, Zurich, Switzerland, January, 2009

"B Physics at Hadron Colliders", Fermi National Accelerator Laboratory Academic Lectures, Batavia, Illinois, February 8th, 2007.

"B Physics at the Tevatron" SSI 2006, 34th SLAC Summer Institute On Particle Physics, Menlo Park, California, July 17-28, 2006

"CDF Experience with Tracking Software," CMS Tracking Workshop, FermiLab, Batavia, Illinois, August 3rd, 2004.

Invited Seminars and Colloquia

Colloquia

"Searches for the Higgs Boson" University of Massachusetts Amherst Physics Colloquium, Amherst, Massachusetts, December 10th, 2008.

"Matter/Antimatter Oscillations" Wayne State University Physics Colloquium, Detroit, Michigan, October 19th, 2006.

"Matter/Antimatter Oscillations" University of Wisconsin Physics Colloquium, Madison, Wisconsin, September 27th, 2006.

Seminars

"CDF Winter 2010 Higgs Results," Fermilab Joint Theoretical-Experimental Physics Seminar, Batavia, Illinois, March, 2010.

"Searches for FCNC Decays Bs(d) to mumu," University of Illinois, Champaign-Urbana, Illinois, December, 2009.

"An Inclusive Search for H-¿WW at CDF," University of Maryland High Energy Physics Seminar, College Park, Maryland, October, 2009

Iowa State University High Energy Physics Seminar, Ames, Iowa, October, 2009

Fermi National Accelerator Laboratory Theory Seminar, FNAL, Illinois, August, 2009

"B Physics at Hadron Colliders: Bs Meson and New B Hadrons", State University of New York, Stony Brook, New York, April 2007.

"Search for FCNC Decays Bs(d) to mumu" Carnegie Mellon University University of Pittsburgh High Energy Physics Seminar, Pittsburgh, Pennsylvania, May 3rd, 2006.

"Searches for FCNC Decays Bs(d) to mumu," University of Minnesota, Minneapolis, Minnesota, February 11th, 2005.

University of Wisconsin-Madison, Madison, Wisconsin, January 25th, 2005.

"Current CDF B Physics Results," Stanford Linear Accelerator Center, Menlo Park, California, October 7th, 2004.

"Rare Beauty and Charm Decays and Indirect Searches for New Physics," University of Toronto, Toronto, Canada April 14th, 2004

Lawrence Berkeley National Laboratory Research Progress Meeting, Berkeley, California March 30, 2004.

University of Michigan HEP/Astro Seminar, Ann Arbor, Michigan, February 9, 2004.

University of Pennsylvania, Philadelphia, Pennsylvania January 26th, 2004

Rutgers High Energy Physics Seminar, Piscataway, New Jersey, November 11, 2003.

MIT Nuclear and Particle Physics Colloquium, Boston, Massachusetts, September 8, 2003.

"Search for Bs to mumu Decays," Notre Dame High Energy Physics Seminar, South Bend, Indiana, February 28, 2003.

Research Statement

My research interests lie in the frontier of fundamental physics. High Energy Physics (HEP) offers some of the most interesting experimental opportunities to expand our knowledge of fundamental physics and discover new physics phenomena. I am simultaneously interested in pursuing a greater understanding of the Standard Model (SM) and in studying the predictions of theories that pose solutions to the fundamental questions not answered by the SM of particle physics. These questions include, but are not limited to, the exact nature of Electroweak Symmetry breaking and how the SM particles acquire mass, how to unify gravity with the other fundamental forces and the nature of dark matter. These questions have led me to pursue a diverse research program including elements such as measurements of SM cross sections, SM Higgs boson searches, searches for new physics particles such as very massive vector bosons, and the scattering of multiple gauge bosons. The unifying theme of this research effort is searches for pairs of SM bosons with decays to leptons.

With the recent discovery of a new boson with properties like that of the Standard Model Higgs boson the Standard Model can be considered to be largely complete. The Higgs mechanism is the source of Electroweak Symmetry breaking which leads to masses for the massive electroweak W and Z bosons and explains the large difference in the strength of the electromagnetic force and the weak force at low energy. Also the Higgs field likely acts as the source mass for the most of the fundamental particles in general. However, evidence from a number of sources indicate that the Standard Model must be part a larger theory. For instance, the Standard Model does not explain the presence of dark mater as observed by astronomical experiments or provide a framework for understanding gravity, the forth force of nature. The study of interactions of multiple gauge bosons that are predicted by gauge theory and Electroweak Symmetry breaking is a sensitive way to search for new physics beyond the Standard Model. For instance the scattering interactions involving two gauge bosons in the initial and final state are sensitive to the presence of extra Higgs bosons, as expected in supersymmetry, which could explain dark matter. Also theses processes are sensitive to new gauge bosons, which may occur in new unification theories. These theories are directly testable by studying the high energy scattering of electroweak gauge bosons. In addition, they involve the study of exotic processes predicted by the Standard Model, but not yet observed, such as quartic gauge coupling or the production of pairs of same sign W bosons. These physics opportunities are newly possible due to the high energy and large integrated luminosities collected by the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) and will be expanded by the energy and luminosity upgrade just completed at the LHC.

On the CMS experiment I study multiboson production physics. Final states involving multiple vector bosons are especially sensitive to new physics. For instance, all of the most sensitive decay channels that were used for detecting the Higgs boson involved two vector bosons in the final state. Also as explained above, models that propose unification of the forces or alternative mechanisms of Electroweak Symmetry breaking can be detected in final states involving multiple vector bosons. My research group has performed measurements of the expected rates of SM production of two vector bosons, direct new physics searches in the same final states and searches for enhancements of

the rates of multiple vector boson production at high energy that are predicted by many models of new physics.

My research group is primarily involved in the study of final states involving ZZ and WZ pairs of bosons. These states are sensitive to the quartic gauge coupling or four Z bosons or two W bosons and two Z bosons, scattering via Higgs bosons, and scattering via higher mass new neutral or charged Higgs or gauge bosons, or the direct production of charged and doubly charged new bosons. Further these studies are sensitive to new physics even if it is the mass of the associated particles are above the energy range that is directly accessed by the LHC.

To further my physics research program I am involved in a number of projects on the CMS experiment concentrating on the muon system. My group worked on construction, installation, commissioning and now opperation of the recent upgrade to the Muon cathode strip chambers (CSCs). Also my group works on radiation testing to demonstrate that the CSCs can work in the high radiation environment of the future high luminosity LHC. In addition, I am investigating the physics potential of various options for upgraded muon detector configurations during the high luminosity running of the HL-LHC. These projects are all designed to improve the muon detection abilities of the experiment, which will in turn enhance searches for new physics involving di-boson signatures.

In conclusion, I have outlined a continuing physics research program that leverages my expertise in muon systems and associated physics to perform searches for new physics at the CMS experiment. This physics program concentrates on di-boson signatures and covers such fundamental issues as Electroweak Symmetry breaking, the unification of forces, and the nature of dark matter. In addition, the physics program also involves measurements of key SM physics signatures involving di-bosons. This research program is conducted at the energy frontier of physics and has the goal of expanding our fundamental knowledge of nature.