

# Elliot Lipeles

## Contact Information

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## Education and Employment

2023-present **Professor, University of Pennsylvania**

2014-2023 **Associate Professor, University of Pennsylvania**

2008-2014 **Assistant Professor, University of Pennsylvania**

2003-2008 **Postdoctoral Fellow, University of California, San Diego**

1995-2003 **Ph.D., California Institute of Technology**  
Thesis Topic: Inclusive Semileptonic  $B$  Decays at CLEO

1991-1995 **B.A., University of Chicago**  
Concentrations in Physics and Mathematics  
College and Departmental Honors

## Current Research Objective

To play a major role in advancing our understanding of what stabilizes the mass of the newly discovered Higgs bosons against quantum corrections and to search for possible ways in which dark matter might be produced in high energy proton collisions.

## Current Research Activities

2013-present Supersymmetry research program:

- (2022-present) RPV Higgsino search with GS Andie Wall
- (2022-present) Long-lived stau search with GS Avi Kahn (nearly complete)
- (2013-2022) Electroweak searches including high-mass, higgsino/compress-spectra, and well-tempered neutralino inspired regions
- (2016-2018) Search for supersymmetric top-quark (stop) decays involving one lepton,
- (2017-2019) RPV B-L SUSY search using reinterpretation of previous ATLAS searches

2009-present Top and Standard Model

- (2023-present) Developing first use of vector boson fusion to  $VVH$  to constrain Higgs self-coupling with PD Prachi Attmasiddha

- (2021-present) Developing first limits on EFT operators using semileptonic dibosons at very high  $m_{VV}$  with GS Riley Xu (nearly complete)
- (2017-2019) Interference of singly and doubly resonant top
- (2019) Top-width measurement
- (2015-2016) First  $WZ$  measurement in Run 2
- (2009-2010) First  $WW$  measurement in Run 1

2008-2023

Higgs research program

- (2008-2023) Search for Invisible Higgs: Broad contributions to the  $ZH$  search in Run 1 and VBF Higgs to invisible searches in Run 1 and Run 2: editor of full Run 2 conference note and paper. Developed novel optimization of background sample generation to minimize theory uncertainties.
- (2008-2012)  $H \rightarrow WW$  observation: missing energy calculation, suppression and modeling of the  $W$ +jets and Drell-Yan backgrounds, optimization, and Monte Carlo modeling for the Vector Boson Fusion (VBF) production channel. Group provided leadership for several publications including Run 1 summary PRD.

2008-present

Trigger upgrade program

- (2021-present) ATLAS HL-LHC L4 EF track pattern recognition co-coordinator
- (2017-2021) ATLAS HL-LHC L4 HTT tracking processor construction manager
- (2019-present) US ATLAS HL-LHC L3 track trigger construction manager
- (2015-2019) US ATLAS HL-LHC L2 trigger construction manager
- (2023-present) Started work neural network track find (currently GNN-based)
- (2021-present) Development of novel methods for track pattern recognition on FPGAs and leading broader development of the simulation for hardware accelerators with students. This was an important component of the commodity hardware task force document and the TDR addendum.
- (2021-2022) Significant contributing member to numerous committees to re-evaluate the ATLAS HL-LHC track trigger plans including the possibility of a two-level trigger with a regional readout and the switch to software plus possible accelerator card solution for the event filter. This included large contributions to the commodity hardware task force document and the TDR addendum.
- (2022) Participant in EF tracking fitting group
- (2017-2021) Lead development of ATCA carrier card and data processor for hardware track trigger (ATLAS L4 manager for the project). Penn is the main hardware designer for the board.
- Editor of Trigger and DAQ technical design report physics and performance chapters, also contributed heavily to the track trigger requirements and specification documents and reviews of the architecture.

- HL-LHC jet and track trigger performance studies
- 2014-present Tracker upgrade program
- Focus on the strips tracker on-detector readout electronics. Closely coupled with my trigger upgrade program.
  - Worked with the Penn Instrumentation Group to design the ABC\* and HCC\* chips, include specification, simulation, and physical testing and radiation tests.

## Past Research Activities and Experience

- 2020-2022 Snowmass Energy Frontier Convenor for Beyond the Standard Model, Model Dependent Investigations Subgroup
- Also participated in pMSSM studies for Snowmass to compare the sensitivity of indirect constraints from precision measurements to direct searches
- 2012-2013 Served on ATLAS's Analysis Model Study Group
- 2012-2013 Served as the ATLAS trigger menu and signature coordinator
- 2008-2014 Trigger rate and cost group, lead original ATLAS resource monitoring effort, served as ATLAS trigger rate group coordinator
- 2006-2008 Contributions to the CMS data acquisition system focused on the commissioning of the event builder.
- 2005-2011 Analysis program for boson pair (diboson) production in CDF data.
- Major expansion of the CDF lepton identification algorithms.
  - $H \rightarrow WW$  search using a matrix element fitting technique.
  - First evidence of  $ZZ$  production in hadron collisions.
  - First observation of  $WZ$  production in hadron collisions.
  - Limits nonstandard model  $WW\gamma/Z$  and  $ZZZ$  couplings in  $lvjj$ ,  $lljj$ ,  $ll\nu\nu$ , and trilepton final states.
- 2005-2006 CDF diboson subgroup co-convenor.
- 2004-2006 Subproject leader of the CDF analysis farm.
- 2004-2005 Measurement of the  $\Lambda_b$  lifetime using the  $J/\psi\Lambda$  decay mode.
- 2004 Developed an interactive monitor for grid jobs running on non-dedicated distributed computing resources.
- 2003-2004 Developed a prototype for the CDF production data processing system that was successfully deployed.
- 2000-2003 Analysis of the fully differential inclusive semileptonic  $B$  decay rate in the CLEO II and II.V data samples using neutrino reconstruction. This yielded a complete model of the sample composition as a function of all nontrivial kinematic variables, which was then used to test Heavy Quark Effective Theory and extract the CKM matrix elements  $V_{ub}$  and  $V_{cb}$ .

2000	Played a key role in the commissioning of the CLEO III detector.
1995-2000	Development of hardware and software for the CLEO III data acquisition system. Contributions include: the full data chain software from VME device drivers and crate control code through the event builder; database access and control GUIs; and digital signal processor code for the Ring Imaging Cherenkov (RICH) and silicon detector digitization boards.
1997	Data acquisition for a beam test of the CLEO III RICH detector.
1993-1995	Analysis of Pioneer 10 & 11 spacecraft data on relativistic electrons in Jupiter's magnetosphere.
1992-1993	Calibration of the Energetic Heavy Ion Counter (EHIC) cosmic ray satellite.

### Honors and Fellowships

2013	Sambamurti Memorial Lectureship, Brookhaven National Laboratory
2010	Sloan Research Fellowship
2001	DPF Snowmass Fellowship
2000	John Stager Stemple Memorial Prize in Physics for outstanding progress in research as demonstrated by an excellent performance on the oral Ph.D. candidacy exam

### Recent Conference Talks and Seminars

Mar 2024	“Future Hadron Colliders”, The Future of High Energy Physics: A New Generation, A New Vision , Aspen
Sept 2021	“The upgrade of the ATLAS experiment: physics potential and new detector features”, PANIC 2021, Lisbon (virtual), Portugal
July 2016	“ATLAS Higgs Results”, SUSY 2016, Melbourne, Australia
Dec 2015	“Higgs to Invisible at ATLAS”, LAPP Journal Club, Cornell, Ithaca, NY
Oct 2015	“Invisible Higgs Experiment”, PITT PACC Workshop: Higgs and Beyond, Pittsburgh
Oct 2015	“ATLAS Phase-2 Trigger”, Coordinating Panel on Advanced Detectors (CPAD), Arlington, Texas
May 2015	“Computing in the ATLAS experiment at the LHC”, PICS Symposium, Philadelphia
October 2013	“Trigger Challenges for HL-LHC: An ATLAS biased review”, CERN Detector Seminar, CERN
August 2013	“SM and BSM Higgs Searches at ATLAS”, Search 2013, Stony Brook
July 2013	“Interplay of Experiment and Theory in Higgs Measurement”, Prospects in Theoretical Physics, Institute for Advanced Study, Princeton
April 2013	“ATLAS Results: A Higgs Centric Update”, BNL Forum 2013, Brookhaven National Lab

- November 2012 “Higgs to WW ll $\nu\nu$  (and l $\nu$ q) at the LHC”, Higgs Coupling 2012
- October 2012 University of Pennsylvania Physics Colloquium
- April 2012 “Search for the Standard Model Higgs Boson in Decays into WW/ZZ with ATLAS”, LHC Workshop at the Princeton Center of Theoretical Physics
- April 2012 University of Delaware Physics Colloquium
- Sept 2011 Invited Talk: “L1 track triggers for ATLAS in the HL-LHC”, Topical Workshop on Electronics for Particle Physics

### Select Talks Members of My Group on Material from My Research

- 2023 Avi Kahn, “Fast tracking on heterogeneous hardware for the ATLAS Event Filter”, CHEP 2023
- 2022 Andie Wall, “Irradiation testing of ASICs for the ATLAS HL-LHC Upgrade”, TWEPP 2022
- 2022 Ben Rosser, “Searches for dark matter with the ATLAS detector”, Pheno2022
- 2020 Ben Rosser, “Searches for invisible Higgs boson decays at the ATLAS experiment”, ICHEP2020
- 2019 Bill Balunas, “Dark Matter searches with the ATLAS Detector”, SUSY2019
- 2019 Bill Balunas, “ATLAS Trigger and Data Acquisition Upgrades for High Luminosity LHC”, ICHEP2016
- 2018 Joana Miguens, “Compressed SUSY searches in ATLAS”, LHCP2018
- 2018 Elodie Resseguieu, “Searches for electroweak production of supersymmetric particles involving the Higgs boson and the higgsino with ATLAS”, SUSY2018
- 2017 Joana Miguens, “SUSY: News from Run 2 searches”, Planck2017
- 2016 Joana Miguens, “The ATLAS Run-2 Trigger: Design, Menu, Performance and Operational Aspects”, ICHEP2016
- 2016 Christian Herwig, “ATLAS jet trigger performance in 2015 data”, ICHEP2016
- 2015 Rami Vanguri, “Search for exotic decays of the Higgs boson with the ATLAS detector”, Lake Louise Winter Institute

### Public Lectures

- July 2013 “The Higgs Boson: What it is and how do we look for it,” Sambamurti Memorial Lectureship, Brookhaven National Laboratory
- July 2013 “The Higgs Boson: What it is and how do we look for it,” Experimental Physics Research Academy (summer high-school program)
- April 2013 “The Higgs Discovery: Giant Experiments to Find the Smallest Specks of Matter”, Penn Science Café
- March 2013 “The Higgs Particle: What Is It and How Has It Been Discovered?”, Knowledge by the Slice

- July 2012 “The Higgs Announcement,” Penn Summer Science Academy (summer high-school program)
- July 2011 “LHC Physics,” Public Lecture at the Aspen Institute for Physics

### Teaching Experience

- Spring 2024 Physics 171 Honors Physics II: Electromagnetism and Radiation, 26 students
- Fall 2023 Physics 170 Honors Physics I: Mechanics and Wave Motion, 26 students
- Spring 2023 Physics 171 Honors Physics II: Electromagnetism and Radiation, 22 students
- Fall 2022 Physics 170 Honors Physics I: Mechanics and Wave Motion, 32 students
- Spring 2022 Physics 171 Honors Physics II: Electromagnetism and Radiation, 19 students
- Fall 2021 Physics 170 Honors Physics I: Mechanics and Wave Motion, 19 students
- Fall 2020 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 54 students online active learning
- Spring 2020 Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 59 students (online) active learning
- Spring 2019 Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 68 students active learning
- Fall 2018 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 67 students active learning
- Spring 2018 Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 57 students active learning
- Fall 2017 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 66 students, active learning
- Spring 2017 Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 107 students, active learning
- Fall 2016 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 71 students, active learning
- Spring 2016 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 72 students, active learning.
- Spring 2015 Physics 414/521: Laboratory in Modern Physics, 19 students.
- Fall 2014 Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 77 students.
- Spring 2014 Physics 414/521: Laboratory in Modern Physics, 8 students.
- Fall 2014 Physics 414/521: Principles of Physics I: Mechanics and Wave Motion, two sections with 110 students.
- Spring 2013 Physics 414/521: Laboratory in Modern Physics, 17 students.
- Spring 2012 Physics 414/521: Laboratory in Modern Physics, 16 students.

Fall 2011	Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 78 students.
Spring 2011	Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 97 students.
Spring 2010	Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 51 students.
Fall 2009	Physics 140/150; Principles of Physics I: Mechanics and Wave Motion, 76 students.
Spring 2009	Physics 141/151; Principles of Physics II: Electromagnetism and Radiation, 75 students.

### Graduate Student Supervision

Saksevul Arias	Saksevul is a first-year student who will be working on neural network particle trackin
Andie Wall	Andie is a fourth-year student working on ITK electronics testing and is working on compress R-parity violating Higgsino searches.
Gwen Gardner	Gwen is a fourth-year student stationed at CERN working on TRT commissioning, Snowmass summary plots, and previously contributed to HTT firmware. She is now working on a thesis analysis for high-pT Higgs to $WW$ with Dylan Rankin
Avi Kahn	Avi is a fifth-year student who contributed significantly to the trigger tracking simulation, particularly in the complex detector mapping and novel algorithm development, and on high $\frac{dE}{dx}$ searches for stau particles and is expected to graduate in summer 2025.
Riley Xu	Riley is a six-year student who has contributed significantly to track-trigger simulation and track trigger hardware development. He was the primary developer of the Hough transform simulation of the commodity hardware evaluation taskforce. He is now deeply involved in the semileptonic diboson EFT study and is expected to graduate in summer 2025.
Ben Rosser (2021)	“Continuing the Search for Nothing: Invisible Higgs Boson Decays and High Luminosity Upgrades at the ATLAS Detector”, received McCormick Fellowship at the University of Chicago, enormous contributions to ITK ASIC simulation which resulted in a US ATLAS Outstanding Graduate Student award.
Elodie Resseguie(2019)	Thesis: “Electroweak Physics at the Large Hadron Collider with the ATLAS Detector: Standard Model Measurement, Supersymmetry Searches, Excesses, and Upgrade Electronics”, received Chamberlian Fellowship at Berkeley Lab and ATLAS and Spring Thesis Awards.
Christian Herwig(2019)	Thesis: ”Targeting Natural Supersymmetry with Top Quarks”, HL-LHC upgrade track trigger, stop squark search with one lepton search, interference of single top production with $t\bar{t}$ production, limits on the top width, simulation and configuration of the data flow the hardware track trigger. Now a postdoc at Fermilab.

- Bill Balunas (2018) Bill searched for VBF Higgs to invisible with Run 2 data is in the final stages of review. In addition, he studied forward jet triggering hardware for the ATLAS upgrades planned for 2021 and 2026. After his defense, Bill started a position at Oxford.
- Rami Vanguri (2015) Rami defended his these June 2015 on Higgs decaying to invisible (dark matter) particles. In addition, he worked on ATLAS trigger rate modeling. Now a research scientist in Bio-informatics at Columbia.
- Doug Schaefer (2014) Doug defended his thesis Apr 2014 on the  $H \rightarrow WW$  discovery and measurement, including a focus on lepton optimization, fake-lepton modeling, missing energy reconstruction, and vector boson fusion measurement. After his defense, Doug started a position as a CERN fellow.
- Josh Kunkle (2013) Josh defended his thesis in July 2013 based on several ATLAS analyses centered on the dilepton plus missing momentum signature, including the search for Higgs decaying invisibly. Started a postdoc at the University of Maryland.
- Tatiana Rodriguez (2011) Co-adviser with Nigel Lockyer. Tatiana completed a project with the CDF experiment and graduated in August 2011.

### **Undergraduate Mentorship**

2023-2024	Riya Miaya
2023-2024	Anya Draves
2023	Steven Chang
2023	Shand Seiffert
2022-2023	Ethan Hu
2021	Mitchell Cornell
2019	Mark Klinger
2019	Samuel Goldstien
2018-2021	Andrew Roberts, honors thesis
2017	Imaad Casim
2017	Nikos Grzesiak
2013-2017	James Sheplock, honors thesis
2013-2014	David Smith

### **Committees and Service**

2023-present	Chair of Faculty Mentorship Committee for Dylan Rankin
2018-present	Faculty Mentorship Committee for Liang Wu
2009,2021-2024	Colloquium Committee
2021-2022	High-energy experiment Faculty Search Committee
2009-2012,2014,2021-2023	Graduate Committee



2021	Lab/Demo oversight committee
2019	Tenure Committee for Christopher Mauger
2016-2018	Undergraduate Committee
2017	High-energy theory Faculty Search Committee
2016-2018	Masters in Medical Physics Advisory Committee
2011-2015	Premajor Advisor for incoming undergraduates
2015	High-energy experiment Faculty Search Committee
2011-2012	Hearings List for the Faculty Grievance Commission

### Publications of which I am a primary author (refereed)

- [1] G. Aad *et al.* [ATLAS], “Tools for estimating fake/non-prompt lepton backgrounds with the ATLAS detector at the LHC,” JINST **18**, no.11, T11004 (2023) doi:10.1088/1748-0221/18/11/T11004 [arXiv:2211.16178 [hep-ex]].
- [2] J. R. Dandoy *et al.* [ATLAS], “Irradiation testing of ASICs for the HL-LHC ATLAS ITk Strip Detector,” JINST **18**, no.02, C02044 (2023) doi:10.1088/1748-0221/18/02/C02044
- [3] J. R. Dandoy *et al.* [ATLAS], “Quality control testing of the HCC ASIC for the HL-LHC ATLAS ITk strip detector,” JINST **18**, no.02, C02026 (2023) doi:10.1088/1748-0221/18/02/C02026
- [4] W. J. Ashmanskas *et al.* [ATLAS], “Verification of simulated ASIC functionality and radiation tolerance for the HL-LHC ATLAS ITk Strip Detector,” JINST **18**, no.01, C01029 (2023) doi:10.1088/1748-0221/18/01/C01029
- [5] G. Aad *et al.* [ATLAS], “Search for invisible Higgs-boson decays in events with vector-boson fusion signatures using  $139 \text{ fb}^{-1}$  of proton-proton data recorded by the ATLAS experiment,” JHEP **08**, 104 (2022) doi:10.1007/JHEP08(2022)104 [arXiv:2202.07953 [hep-ex]].
- [6] G. Aad *et al.* [ATLAS], “Operation of the ATLAS trigger system in Run 2,” JINST **15**, no.10, P10004 (2020), 60 pages, doi:10.1088/1748-0221/15/10/P10004 [arXiv:2007.12539 [physics.ins-det]].
- [7] V. Balasubramanian, J. J. Heckman, E. Lipeles, and A. P. Turner, Phys. Rev. D **103**, no.6, 066024 (2021), 11 pages, doi:10.1103/PhysRevD.103.066024 [arXiv:2012.09182 [hep-th]].
- [8] G. Aad *et al.* [ATLAS], “Operation of the ATLAS trigger system in Run 2,” JINST **15**, no.10, P10004 (2020), 59 pages, doi:10.1088/1748-0221/15/10/P10004 [arXiv:2007.12539 [physics.ins-det]].
- [9] G. Aad *et al.* [ATLAS], “ATLAS data quality operations and performance for 2015–2018 data-taking,” JINST **15**, no.04, P04003 (2020), 43 pages, doi:10.1088/1748-0221/15/04/P04003 [arXiv:1911.04632 [physics.ins-det]].
- [10] G. Aad *et al.* [ATLAS], “Searches for electroweak production of supersymmetric particles with compressed mass spectra in  $\sqrt{s} = 13 \text{ TeV}$   $pp$  collisions with the ATLAS detector,” Phys. Rev. D **101**, no.5, 052005 (2020), 46 pages, doi:10.1103/PhysRevD.101.052005 [arXiv:1911.12606 [hep-ex]].

- [11] G. Aad *et al.* [ATLAS], “ATLAS data quality operations and performance for 2015–2018 data-taking,” JINST **15** (2020) no.04, P04003 doi:10.1088/1748-0221/15/04/P04003 [arXiv:1911.04632 [physics.ins-det]].
- [12] G. Aad *et al.* [ATLAS], “Search for chargino-neutralino production with mass splittings near the electroweak scale in three-lepton final states in  $\sqrt{s}=13$  TeV  $pp$  collisions with the ATLAS detector,” Phys. Rev. D **101**, no.7, 072001 (2020), 32 pages, doi:10.1103/PhysRevD.101.072001 [arXiv:1912.08479 [hep-ex]].
- [13] M. Aaboud *et al.* [ATLAS], “Search for chargino-neutralino production using recursive jigsaw reconstruction in final states with two or three charged leptons in proton-proton collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector,” Phys. Rev. D **98**, no.9, 092012 (2018), 42 pages, doi:10.1103/PhysRevD.98.092012 [arXiv:1806.02293 [hep-ex]].
- [14] M. Aaboud *et al.* [ATLAS], “Probing the quantum interference between singly and doubly resonant top-quark production in  $pp$  collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector,” Phys. Rev. Lett. **121**, no.15, 152002 (2018), 20 pages, doi:10.1103/PhysRevLett.121.152002 [arXiv:1806.04667 [hep-ex]].
- [15] M. Aaboud *et al.* [ATLAS], “Search for invisible Higgs boson decays in vector boson fusion at  $\sqrt{s} = 13$  TeV with the ATLAS detector,” Phys. Lett. B **793**, 499-519 (2019), 42 pages, doi:10.1016/j.physletb.2019.04.024 [arXiv:1809.06682 [hep-ex]].
- [16] M. Aaboud *et al.* [ATLAS Collaboration], “Search for electroweak production of supersymmetric states in scenarios with compressed mass spectra at  $\sqrt{s} = 13$  TeV with the ATLAS detector,” Phys. Rev. D **97**, no. 5, 052010 (2018), 35 pages, doi:10.1103/PhysRevD.97.052010 [arXiv:1712.08119 [hep-ex]].
- [17] M. Aaboud *et al.* [ATLAS Collaboration], “Search for top-squark pair production in final states with one lepton, jets, and missing transverse momentum using  $36 \text{ fb}^{-1}$  of  $\sqrt{s} = 13$  TeV  $pp$  collision data with the ATLAS detector,” JHEP **1806**, 108 (2018), 95 pages, doi:10.1007/JHEP06(2018)108 [arXiv:1711.11520 [hep-ex]].
- [18] M. Aaboud *et al.* [ATLAS Collaboration], “Search for electroweak production of supersymmetric particles in final states with two or three leptons at  $\sqrt{s} = 13$  TeV with the ATLAS detector,” Eur. Phys. J. C **78**, no. 12, 995 (2018), 36 pages, doi:10.1140/epjc/s10052-018-6423-7 [arXiv:1803.02762 [hep-ex]].
- [19] M. Aaboud *et al.* [ATLAS Collaboration], “Measurement of the  $W^{\pm}Z$  boson pair-production cross section in  $pp$  collisions at  $\sqrt{s} = 13$  TeV with the ATLAS Detector,” Phys. Lett. B **762**, 1 (2016) doi:10.1016/j.physletb.2016.08.052 [arXiv:1606.04017 [hep-ex]].
- [20] G. Aad *et al.* [ATLAS Collaboration], “Search for invisible decays of a Higgs boson using vector-boson fusion in  $pp$  collisions at  $\sqrt{s} = 8$  TeV with the ATLAS detector,” JHEP **1601**, 172 (2016) doi:10.1007/JHEP01(2016)172 [arXiv:1508.07869 [hep-ex]].
- [21] G. Aad *et al.* [ATLAS Collaboration], “Constraints on new phenomena via Higgs boson couplings and invisible decays with the ATLAS detector,” JHEP **1511**, 206 (2015) doi:10.1007/JHEP11(2015)206 [arXiv:1509.00672 [hep-ex]].
- [22] G. Aad *et al.* [ATLAS Collaboration], “Observation and measurement of Higgs boson decays to  $WW^*$  with the ATLAS detector,” Phys. Rev. D **92**, no. 1, 012006 (2015) doi:10.1103/PhysRevD.92.012006 [arXiv:1412.2641 [hep-ex]].

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- [30] E. Lipeles *et al.* [ATLAS Collaboration], “Resource utilization by the ATLAS High Level Trigger during 2010 and 2011 LHC running,” J. Phys. Conf. Ser. **396**, 012046 (2012).
- [31] G. Aad *et al.* [ATLAS], “Measurement of  $W^+W^-$  production in pp collisions at  $\sqrt{s}=7$  TeV with the ATLAS detector and limits on anomalous WWZ and  $WW\gamma$  couplings,” Phys. Rev. D **87**, no.11, 112001 (2013), 29 pages, [erratum: Phys. Rev. D **88**, no.7, 079906 (2013)] doi:10.1103/PhysRevD.87.112001 [arXiv:1210.2979 [hep-ex]].
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- [38] E. Lipeles [ATLAS Collaboration], “L1 track triggers for ATLAS in the HL-LHC,” JINST **7**, C01087 (2012).
- [39] T. Aaltonen *et al.* [CDF Collaboration], “Measurement of  $ZZ$  production in leptonic final states at  $\sqrt{s}$  of 1.96 TeV at CDF,” Phys. Rev. Lett. **108**, 101801 (2012) [arXiv:1112.2978 [hep-ex]].
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