Philip Chang

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Current Research Objectives

My research focuses on multiboson final states as sensitive channels for discovering new physics and precision probes of electroweak interactions, testing the Standard Model at its limits while remaining open to unexpected discoveries. I also contribute to shaping the physics case for future colliders such as the muon collider, where a holistic tracker design can improve tracking performance and help mitigate beam-induced background challenges.. In parallel, I advance computing for high-energy physics through leadership at the UF Tier-2 center. My work includes developing large-scale data processing strategies and leveraging GPUs and heterogeneous computing architectures to accelerate CMS workflows and enable fast-turnaround analyses.

Education and Employment

2022 - Present | **University of Florida**, Gainesville, FL, USA
Assistant Professor

2017 - 2022 | **University of California, San Diego**, La Jolla, CA, USA
Postdoctoral Researcher

2011 - 2017 | **University of Illinois Urbana–Champaign**, Urbana, IL, USA
Ph.D. in Physics
Dissertation — Vector boson fusion produced H⟶WW* and extended Higgs sector search
Advisor — Mark Neubauer

2005 - 2009 | **University of Illinois Urbana–Champaign**, Urbana, IL, USA
B.Sc. in Physics
Thesis — Search for $B_s \longrightarrow J/\psi K*$ with CDF detector
Advisor — Kevin Pitts

Research Experience

2024 - Current | **US Muon Collider Collaboration**

2017 - Current | **CMS Experiment**, CERN

2011 - 2017 | **ATLAS Experiment**, CERN

2010 - 2011 | **AdS/CFT studies**, University of Illinois Urbana-Champaign

2008 - 2009 | **CDF Experiment**, Fermilab

Technical and Computing Experience

2023 - Current | **UF Tier-2 Computing Center Manager**

2023 - Current | **Line Segment Tracking with GPU as-a-service approach**

2023 - Current | **Rapid and Efficient Analysis software with Columnar Tools**
Benchmarking workflows, acceleration of columnar tools with GPUs

2019 - Current | **Line Segment Tracking (LST) Algorithm for HL-LHC**

2011 - 2017 | **Fast TracKer (FTK)**
Second Stage Board, Extrapolator Algorithm, Track Finding Algorithm

Analysis Experience

2022 - Current | **Vector Boson Scattering Produced VVH to 0, 1, 2 and same-sign leptons**
Determining the quartic Higgs couplings to W and Z bosons

2021 - Current | **Search for New Physics in Three Massive Gauge Boson Processes**
Comprehensive search for subtle deviations from SM in WWW, WWZ, WZZ, ZZZ processes

2023 - 2025 | **Simultaneous Measurement of WWZ and ZH→WW Processes**
Most precise measurement of WWZ cross section

2022 - 2024 | **Vector Boson Scattering Produced WH to 1 lepton + bb**
Determining the relative sign of Higgs couplings to W and Z bosons

2019 - 2020 | **First Observation of Three Massive Gauge Boson Processes**
Establishing the SM process of WWW, WWZ, WZZ, ZZZ

2017 - 2019 | **Search for Three W Boson Processes**
Searched for SM process of WWW and probed photophobic axion models

2012 - 2014 | **Search for exotic Higgs decay to additional scalars in bbμμ final state**
Searched for Dark Matter candidate that could explain Fermi-LAT signal

2012 - 2014 | **First Evidence of Vector Boson Fusion Produced H→WW**
Study Higgs properties and place best constraint on Higgs to Fermion couplings

2012 - 2014 | **First Observation of H→WW**
Study Higgs properties and place best Higgs to W boson couplings.

2011 - 2012 | **Search for H→WW and Observation of New Resonance at 125 GeV**
Search for the predicted Higgs boson; Observed new resonance that led to Nobel Prize

2009 | **Search for $B_s \to J/\psi K^*$**
Search to measure B_s mixing parameter

Grants Awarded

06/2024 - 03/2028 | **Experimental Research at the Energy Frontier in High Energy Physics**
DOE
Andrey Korytov (PI), Philip Chang (co-PI), Jaco Konigsberg (co-PI), Yuta Takahashi (co-PI), Guenakh Mitselmakher (co-PI), Paul Avery (co-PI)

01/2025 - 12/2025 | **Charting a course toward rapid turnaround of HL-LHC scale analyses: Benchmarking current capabilities and exploring the acceleration of columnar processing via heterogeneous architectures**
University of Nebraska-Lincoln (Sponsor), NSF (Prime Sponsor)
Philip Chang (PI)

01/2024 - 12/2025 | **USCMS Software and Computing - UF Tier-2 Computing Center**
University of Nebraska-Lincoln (Sponsor), NSF (Prime Sponsor)
Philip Chang (PI)

01/2024 - 12/2024 | **USCMS HL-LHC R&D Initiative: Deploying GPU algorithms through SONIC**
University of Nebraska-Lincoln (Sponsor), NSF (Prime Sponsor)
Philip Chang (PI)

05/2023 - 3/2024 | **Energetic Tri-bosons as Heralds of New Physics**
DOE
Philip Chang (PI)

01/2023 - 08/2026 | **QuarkNet UF**
University of Notre Dame (Sponsor), NSF (Prime Sponsor)
Philip Chang (PI)

Professional Service and Leadership

2026 - Current | **Outreach Coordinator**
US Muon Collider Collaboration

2023 - Current | **HL-LHC R&D Algorithms Coordinator**
US CMS Operations Program

2023 - Current | **Management Board (Early Career Member)**
LHC Physics Center at Fermilab

2025 - Current | **Executive Committee Member (Elected)**
US LHC User Association (USLUA)

2023 - Current | **Research Computing Advisory Committee**
University of Florida

2024 | **Reviewer for two different occasions**
DOE

2023 - 2025 | **35th Auditor of AKPA (Elected)**
Association of Korean Physicists in America (AKPA)

2023 - 2025 | **USCMS Mentorship Committee**
LHC Physics Center at Fermilab

2020 - 2022 | **LHC Electroweak Multiboson Subgroup co-Convener**
LHC Physics Center at CERN (LPCC)

2015 - 2016 | **Higgs Working Group Trigger co-Contact**
ATLAS Collaboration

2015 - 2016 | **VBF Trigger Group co-Coordinator**
ATLAS Collaboration

Organizational Activities for the Profession

2025 | **Lepton Photon 2025**, Madison, WI
Computing AI & ML Session Chair

2024 | **37th US-Korea Conference**, San Francisco, CA
Technical Symposium Session (A-1 Physics) Chair

2024 | **Inaugural US Muon Collider Community Meeting**, Fermilab, IL
Plenary Session Chair

2024 | **Inaugural US Muon Collider Community Meeting**, Fermilab, IL
Organizing Committee

2024 | **Mid-Florida Section QuarkNet Day**, Gainesville, FL
Host

2023 | **90th Annual Meeting of the Southeastern Section of the APS**
Parallel Session Chair

2021 | **EXPAND Mentorship Program**, UCSD, San Diego, CA
co-Coordinator

Awards & Honors and Fellowships

2025 | **Breakthrough Prize in Fundamental Physics**
Breakthrough Prize Board
as a part of the ATLAS and CMS Collaboration

2022 | **Outstanding Young Research Award**
Association of Korean Physicist in America (AKPA)

2022 - 2021 | **Distinguished Researcher**
LHC Physics Center (LPC) at Fermilab

2022 - 2021 | **Giulio Ascoli Award**
University of Illinois Urbana-Champaign

2014 | **Outstanding Graduate Student Award**
US ATLAS

2014 | **Young Physicist Lightning Round Winner**
US LHC User Association (USLUA)

2025 | **High Energy and Particle Physics Prize**
European Physical Society
as a part of the ATLAS Collaboration

2013 | **University Fellowship**
University of Illinois Urbana-Champaign

2008 | **Undergraduate Research Scholar**
Shell Foundation

2004 | **Semi-finalist**
US Physics Team for 35th International Physics Olympiad

Department Committees and Service

2025 | **Director of Undergraduate Labs Faculty Search Committee**

2024 - Current | **Undergraduate Student Awards Committee**

2025 - Current | **Computing Committee co-Chair**

2025 - Current | **Ombuds**

2024 - 2025 | **Preliminary Exam Committee**

2024 - 2025 | **Large Course Teaching Committee**

2024 - 2025 | **Grad Student Affairs Committee (GSAC)**

2023 - 2025 | **Computing Committee**

2023 | **Artificial Intelligence Committee**

2023 (Fall) | **Faculty Meeting Recorder**

2023 | **High-Energy Physics Experiment faculty search committee.**

2023 | **Institute for High Energy Physics and Astrophysics (IHEPA) fellowship selection committee.**

Graduate Student Supervision

2025 - Current | **Alexandra Aponte Utani**, PhD Student
Vector Boson Scattering Produced VVH to constrain trilinear Higgs couplings
LST Algorithm Development for pT2 objects
LST with GPU as-a-service approach

2025 - Current | **Cedric Broussard**, PhD Student

2022 - Current | **Matthew Dittrich**, PhD Student
WWZ and ZH➔WW Cross section Measurement
LST Algorithm Development for pT2 objects

2022 - 2025 | **Eslam Zenhom**, PhD Awarded in 2025
Vector Boson Scattering Produced VVH to 0 leptons in semi-merged final state
Thesis - A Semi-Merged All-Hadronic Search for Anomalous C2V Couplings in VVH Production

2023 - 2024 | **Mayra Silva**, MSc Awarded in 2024
Studying Graph Neural Network applied to LST

Undergraduate Student Supervision

2023 - Current | **Kyrylo Sokolov**, BSc Student
Muon Collider Simulation Studies for Boosted Jet Reconstruction

2023 - Current | **Hubert Pugzlys**, BSc Student, IRIS-HEP Fellow
Studying Effects of Multi-Layer GNN to LST, Muon Collider Tracking Studies

2024 - Current | **Trevor Sabitsch**, BSc Student, IRIS-HEP Fellow
R&D LST tracking with GPU as-a-service for CMS Event Reconstruction

2023 - 2025 | **Joseph Mezzetti**, BSc Student
Generating Signal Samples for Dark Photon and tWZ / ttZ processes

2024 - 2025 | **Cedric Broussard**, BSc
Study of effects of dim6 SMEFT operators on tWZ and ttZ processes
➔ University of Florida Physics PhD program

2024 - 2025 | **Amilqar Karam**, BSc
Accelerating Neural Network Inference with Boosted Decision Trees via FPGA
➔ Johns Hopkins University Physics PhD program

2024 - 2025 | **Tsion (Zion) Dessalegn**, PURSUE Intern Program
Designing and optimizing tWZ signal region

2023 - 2025 | **Samuel Sebastian**, BSc Student

Designing and optimizing tWZ signal region

Postdoctoral Scholar Supervision

2023 - Current | **Dr. Kelci Mohrman**
Simultaneous WWZ and ZH⟶WW Cross Section Measurement
Optimizing SM Sensitivity to Vector Boson Scattering Produced VVH
Studying Graph Neural Network applied to Line Segment Tracking
Studying dim6 SMEFT Operator Effects on tWZ/ttZ processes
R&D LST tracking with GPU as-a-service approach
Developing Rapid and Efficient Analysis Software with Columnar Tools
GPU acceleration of Columnar Analysis Tools
TOP Physics Analysis Group (PAG) EFT Subgroup Convener
Standard Model Physics PAG EFT forum Contact

Selected Talks

2025 | **Triboson Physics**
Plenary Session Talk (Invited)
10/2025 Multi-boson Interactions Workshop 2025, Waltham, MA

2025 | **Measurement of WWZ and ZH production cross sections at √s = 13 and 13.6 TeV**
Parallel Session Talk (Invited)
08/2025 KSEA US-Korea Conference, Atlanta, GA

2025 | **Extreme Computing**
Plenary Session Talk (Invited)
07/2025 Physics At The Highest Energies With Colliders (Galileo Galilei Institute), Florence, Italy

2025 | **Recent LHC Results**
Plenary Session Talk (Invited)
05/2025 Pheno 2025, Pittsburgh, PA

2025 | **Computing R&D: How we get to our targets**
Parallel Session Talk (Invited)
05/2025 LHCP 2025, Taipei, Taiwan

2025 | **Forging New Paths to Unveil the Electroweak Sector**
Colloquium
03/2025 Univ. of Florida, Gainesville, FL

2025 | **Enhancing Particle Physics Discovery Through Computational Innovation**
Parallel Session Talk
03/2025 KSEA Southeastern Regional Conference, Orlando, FL

2024 | **Muon Collider the Dream Machine**
Parallel Session Talk
08/2024 KSEA US-Korea Conference, San Francisco, CA

2024 - 2025 | **Higgs Physics: What is in the vacuum?**
Seminar (Invited)
06/2025 PURSUE (USCMS) Program, Fermilab (Virtual)
07/2024 PURSUE (USCMS) Program, Fermilab (Virtual)

2024 | **GPU Programming**
Lecture (Invited)

05/2024 HSF-India HEP Software Workshop, Delhi, India

2024 | **AI for Particle Tracking**
Parallel Session Talk
03/2024 KSEA Southeastern Regional Conference, Gainesville, FL

2024 | **LHC Future Opportunities**
Plenary Session Talk (Invited)
03/2024 The Future of High Energy Physics: A New Generation, A New Vision (Aspen Winter Conference), Aspen, CO

2023 | **Line Segment Tracking at CMS**
Parallel Session Talk
05/2023 Computing in High Energy & Nuclear Physics (CHEP), Norfolk, VA

2022 | **Recent CMS results on Standard Model Physics**
Parallel Session Talk
09/2022 Conference on the Intersection of Particle and Nuclear Physics, Lake Buena Vista, FL

2022 | **Recent CMS results on Higgs physics**
Parallel Session Talk
08/2022 Conference on the Intersection of Particle and Nuclear Physics, Lake Buena Vista, FL

2022 - 2023 | **New frontiers of electroweak physics at the LHC**
Colloquium and Seminars (Invited)
05/2023 PKU / SJTU Collider Physics Forum, Virtual
09/2022 Univ. of Tennessee, Knoxville HEP Seminar, Knoxville, TN
05/2022 Korea Advanced Institute of Science & Technology Colloquium, Daejeon, Korea
05/2022 AKPA–KPS Joint Symposium, Korea (Virtual)
03/2022 Univ. of Alabama Colloquium, Tuscaloosa, AL
03/2022 Univ. of Notre Dame Colloquium, Notre Dame, IN
01/2022 Univ. of Florida Colloquium, Gainesville, FL

2020 - 2022 | **Observation of production of three massive gauge boson**
Seminars (Invited)
01/2022 Univ. of Florida HEP Seminar, Gainesville, FL (Virtual)
03/2021 Univ. of Illinois HEP Seminar, Urbana, IL (Virtual)
12/2020 Univ. of Pittsburgh HEP Seminar, Pittsburgh, PA (Virtual)
10/2020 Univ. of California Santa Barbara HEP Seminar, Santa Barbara, CA (Virtual)
10/2020 Univ. of Michigan HEP Seminar, Ann Arbor, MI (Virtual)
09/2020 Univ. of Pennsylvania HEP Seminar, Philadelphia, PA (Virtual)
09/2020 Univ. of Maryland HEP Seminar, College Park, MD (Virtual)
09/2020 KSU/KU/UNL Joint HEP Seminar, Kansas / Nebraska (Virtual)
09/2020 Fermilab Wine & Cheese Seminar, Batavia, IL (Virtual)
08/2020 Korea Institute for Advanced Study HEP Seminar, Seoul, Korea
08/2020 Univ. of Seoul HEP Seminar, Seoul, Korea
08/2020 Seoul National University HEP Seminar, Seoul, Korea
07/2020 Hanyang University HEP Seminar, Seoul, Korea
07/2020 Yonsei University HEP Seminar, Seoul, Korea
07/2020 Korea University HEP Seminar, Seoul, Korea
06/2020 Rice University HEP Seminar, Houston, TX (Virtual)
06/2020 Harvard/MIT LPPC Seminar, Boston, MA (Virtual)
05/2020 UC San Diego HEP Seminar, San Diego, CA (Virtual)

2021 | **Multiboson physics at CMS**
Parallel Session Talk (Invited)
04/2021 Korean Physical Society Spring Meeting — Pioneer Symposium, Korea (Virtual)

2020 | **Search for heavy triboson production in leptonic final states**
Parallel Session Talk
07/2020 ICHEP 2020, Prague (Virtual)

2020 | **Parallelizable Track Pattern Recognition in HL-LHC**
Parallel Session Talk

04/2020 Connecting the Dots Workshop, Princeton, NJ (Virtual)

2019 | **Measurements of triple gauge boson production in ATLAS and CMS**
Workshop Talk (Invited)
07/2019 Physics Workshop at the LPC: Multibosons at the Energy Frontier, Batavia, IL

2019 | **Rare EW multiboson at LHC**
Plenary Session Talk
05/2019 LHCP 2019, Puebla, Mexico

2019 | **Electroweak physics with multibosons at CMS**
Parallel Session Talk
05/2019 Pheno 2019, Pittsburgh, PA

2019 | **Search for the SM production of WWW events**
Seminar (Invited)
01/2019 LHC Physics Center Physics Forum, Batavia, IL

2016 | **Searches for new physics in the Higgs sector**
Seminar (Invited)
03/2016 Univ. of Pennsylvania (HEP), Philadelphia, PA

2015 - 2016 | **First evidence for vector-boson fusion H→WW**
Seminar (Invited)
02/2016 Univ. of Cincinnati HEP Seminar, Cincinnati, OH
04/2015 Univ. of Pittsburgh HEP Seminar, Pittsburgh, PA

2015 | **First evidence for vector-boson fusion H→WW**
Parallel Session Talk
04/2015 APS April Meeting, Baltimore, MD

2015 | **Advanced Analysis Technique: Squeezing out information**
Workshop Talk (Invited)
11/2015 4th Chicagoland Pheno–ATLAS Workshop, Chicago, IL

2015 | **ATLAS VBF Trigger Overview**
Workshop Talk (Invited)
01/2015 3rd Chicagoland ATLAS–Pheno Meeting, Chicago, IL

2014 | **Higgs Properties**
Plenary Talk
09/2014 Physics in Collisions 2014, Bloomington, IN

Selected Talks From Members of My Group on Material from My Research

2025 | **Dr. Mohrman, Towards rapid and efficient columnar-based analyses at scale**
Workshop Talk (Invited)
07/2025 Python in HEP (PyHEP) Developer's Workshop 2025

2025 | **Dr. Mohrman, Multiboson production in CMS**
Parallel Session Talk
05/2025 Pheno 2025, Pittsburgh, PA

2025 | **Dr. Mohrman, Exploring nature through the interactions of multiple heavy particles**
Seminar (Invited)
04/2025 Cornell University HEP Seminar, Ithaca, NY

2025 | **Dr. Mohrman, WWZ measurement at 13 and 13.6 TeV with 200 fb^{-1}**
CMS Week Plenary Physics Session (CMS Collaboration Internal)

02/2025 CMS Collaboration, CERN, Geneva

Public Lectures

2024 | **An Invitation to Imagine Something from Nothing**
Public Lecture (Invited)
03/2024 Aspen Center for Physics, Aspen, CO
09/2024 Galesville Astrophysical Society

2024 | **New Frontiers of Electroweak Physics**
Public Lecture
02/2024 Mid-Florida QuarkNet Day

2022 | **Then and Now: Developments in the Large Hadron Collider**
Public Lecture
12/2022 Particle Fever — Science on Screen, Enzian Theater, Maitland FL

Teaching Experience

Fall 2025 | **PHY2060: Enriched Physics 1 w/ Calc**, Enrollment 40
Instructor

Spring 2025 | **PHY2048: Physics 1 w/ Calc**, Enrollment 1102*, GatorEval Score: 4.30
Instructor
*Primarily instructed a subset of students of 121, who registered to the extra sessions that the department opened last minute to specially accommodate increased incoming Freshmen to UF

Fall 2024 | **PHY2048: Physics 1 w/ Calc**, Enrollment 594, GatorEval Score: 4.26
Instructor

Spring 2024 | **PHY2048: Physics 1 w/ Calc**, Enrollment 903, GatorEval Score: 3.53
Instructor

Fall 2023 | **PHY2048: Physics 1 w/ Calc**, Enrollment 586, GatorEval Score: 3.31
Instructor

Fall 2022 | **PHY2049: Physics 2 w/ Calc**, Enrollment 81, GatorEval Score: 4.38
Led 3 discussion sessions

Publications

As a member of the CMS collaboration (and previously ATLAS collaboration) I am an author on over 1100 articles published on refereed journals. Full list of publications can be found at https://inspirehep.net/authors/1054464. Below I list a selected list of publications of which I am a primary author.

Selected Publications

1. CMS Collaboration, "Measurement of WWZ and ZH Production Cross Sections at $\sqrt{s}$ = 13 and 13.6 TeV," *Phys. Rev. Lett.*, **135**(9), 091802, 2025, doi:10.1103/6z3d-zjw4, arXiv:2505.20483 [hep-ex]

2. CMS Collaboration, "Study of WH production through vector boson scattering and extraction of the relative sign of the W and Z couplings to the Higgs boson in proton–proton

collisions at $\sqrt{s}$ = 13 TeV," *Phys. Lett. B*, **860**, 139202, 2025, doi:10.1016/j.physletb.2024.139202, arXiv:2405.16566 [hep-ex]

3. CMS Collaboration, "Observation of the Production of Three Massive Gauge Bosons at $\sqrt{s}$ = 13 TeV," *Phys. Rev. Lett.*, **125**(15), 151802, 2020, doi:10.1103/PhysRevLett.125.151802, arXiv:2006.11191 [hep-ex]

4. CMS Collaboration, "Search for the production of $W^{\pm}W^{\pm}W^{\mp}$ events at $\sqrt{s}$ = 13 TeV," *Phys. Rev. D*, **100**(1), 012004, 2019, doi:10.1103/PhysRevD.100.012004, arXiv:1905.04246 [hep-ex]

5. ATLAS and CMS Collaborations, "Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at $\sqrt{s}$ = 7 and 8 TeV," *JHEP*, **08**, 045, 2016, doi:10.1007/JHEP08(2016)045, arXiv:1606.02266 [hep-ex]

6. ATLAS Collaboration, "Observation and measurement of Higgs boson decays to WW," *Phys. Rev. D*, **92**(1), 012006, 2015, doi:10.1103/PhysRevD.92.012006, arXiv:1412.2641 [hep-ex]

7. ATLAS Collaboration, "Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC," *Phys. Lett. B*, **726**, 88–119, 2013, erratum *Phys. Lett. B*, **734**, 406–406, 2014, doi:10.1016/j.physletb.2013.08.010, erratum doi:10.1016/j.physletb.2014.05.011, arXiv:1307.1427 [hep-ex]

8. ATLAS Collaboration, "Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC," *Phys. Lett. B*, **716**, 1–29, 2012, doi:10.1016/j.physletb.2012.08.020, arXiv:1207.7214 [hep-ex]

9. G. Niendorf, T. Reid, P. Wittich, P. Elmer, B. Wang, et al., "Line Segment Tracking in the HL-LHC," arXiv:2207.08207 [physics.ins-det], 2022

10. P. Chang, P. Elmer, Y. Gu, V. Krutelyov, G. Niendorf, et al., "Segment Linking: A Highly Parallelizable Track Reconstruction Algorithm for HL-LHC," *J. Phys. Conf. Ser.*, **2375**(1), 012005, 2022, doi:10.1088/1742-6596/2375/1/012005, arXiv:2209.13711 [physics.ins-det]

11. CMS Collaboration, "First observation of production of three massive gauge bosons," *PoS ICHEP2020*, **2021**, 325, doi:10.22323/1.390.0325

12. ATLAS and CMS Collaborations, "Studies of rare electroweak multiboson interactions at the LHC," *PoS LHCP2019*, **2019**, 107, doi:10.22323/1.350.0107

13. V. Cavaliere, J. Adelman, P. Albicocco, J. Alison, L.S. Ancu, et al., "Design of a hardware track finder (Fast Tracker) for the ATLAS trigger," *JINST*, **11**(02), C02056, 2016, doi:10.1088/1748-0221/11/02/C02056

14. G. Volpi, J. Adelman, P. Albicocco, J. Alison, L.S. Ancu, et al., "The ATLAS fast tracker processor design," *PoS VERTEX2015*, **2015**, 040, doi:10.22323/1.254.0040

15. J. Anderson, A. Andreani, A. Andreazza, A. Annovi, M. Atkinson, et al., "A fast hardware tracker for the ATLAS trigger system," *Nucl. Instrum. Meth. A*, **718**, 258–259, 2013, doi:10.1016/j.nima.2012.11.133

16. J. Anderson, A. Andreani, A. Andreazza, A. Annovi, M. Atkinson, et al., "FTK: A Fast Track Trigger for ATLAS," *JINST*, **7**, C10002, 2012, doi:10.1088/1748-0221/7/10/C10002

17. CMS Collaboration, "Line Segment Tracking: Improving the Phase-2 CMS High Level Trigger Tracking with a Novel, Hardware-Agnostic Pattern Recognition Algorithm," arXiv:2407.18231 [hep-ex], 2024