Lindsey Gray

Curriculum Vitae

Contact

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Education

- Ph.D. Physics, University of Wisconsin at Madison, 2012

  Dissertation: *A Measurement of the $Z\gamma$ Cross Section and Limits on Anomalous Triple Gauge Couplings at $\sqrt{s}$ = 7 TeV Using CMS*

  Advisor: Sridhara Dasu

- B.S. with majors in Physics and Mathematics, with honors, University of Florida, 2007.

Leadership

***smartpixels* coordinator** - (9 institutes, roughly 20 active contributors), January 2024 - Present: Developing the first generation of intelligent detector systems using low-power real time readout electronics with integrated machine learning algorithms for data reduction and enhanced physics capabilities.

Future Collider Software Development - (5 people), September 2025 - Present: Leading a small team of software developers to investigate the applicability of HL-LHC software framework research to FCCee and The Muon Collider.

USCMS L2 for HL-LHC Software and Computing - (roughly 20 FTE), July 2021 - October 2025: Directing R&D within USCMS to develop computing technologies and infrastructure to achieve the scientific goals of HL-LHC.

CMS ML Innovation Group Convener - June 2020 - July 2021: New group connecting CMS physics analyses and detector reconstruction to bleeding edge machine learning technologies. Organizing CMS ML journal club and hackathons.

Coffea Project Lead - (5-10 people core, hundreds of users), October 2019 - Present: Leading, developing, maintaining columnar analysis software for HEP.

ML4RECO Subgroup Leader - (10 people), September 2019 - July 2023: Leading development of fully ML-based event reconstruction. Focusing on imaging calorimetry and particle flow. Focusing on methodologies and model deployment.

MIP Timing Detector (MTD) performance group convener - (20 people), August 2018 - September 2019

MTD interim system manager - (32 Institutes), June 2017 - July 2018

Precision timing working group convener - (30 people), January 2016 - May 2017

Anomalous gauge coupling contact - (taskforce, 4 people), January 2016 - January 2017

e-γ physics object group convener - (30 people), January 2014 - December 2015

Photon identification sub-convener for the e-γ physics object group - (5 people), 2013

Academic Positions Held

- Scientist (tenured), Fermilab, September 2020 - Present
- Associate Scientist (tenure track), Fermilab, June 2015 - September 2020
- Research Associate, Fermilab, November 2012 - June 2015
- Research Assistant, University of Wisconsin - Madison, 2008 - November 2012
- Teaching Assistant, University of Wisconsin - Madison, 2007 - 2008
- Undergraduate Research Assistant, University of Florida, 2004 - 2007

Grants

- Fermilab LDRD: "Silicon precision timing detectors for minimum ionizing particles", 2017-2019, $500k
- Fermilab LDRD: "Graph Neural Networks for Accelerating Calorimetry and Event Reconstruction", 2019-2021, $480k
- DOE Grant: "Designing Smart Detectors with a ML-to-Silicon Platform", 2025-2026, $350k
- Fermilab LDRD: "CODE4hep: Modern Software Infrastructure for Future Collider Experiments", 2025-2027, $350k

Research Experience

As Staff

This work was done reporting to Dr. Rob Harris, Dr. Joel Butler, Dr. Panagiotis Spentzouris, Dr. Kurt Biery, Dr. Rob Kutschke, and Dr. V. Daniel Elvira at Fermilab and CERN.

- **ttH$\gamma\gamma$:** (2025 - present) I am working with the CMS Higgs to two photon group on the measurement of top-associated Higgs production. I help develop the analysis framework and guide a student in developing additions to the analysis and corresponding EFT measurements.
- **Future Collider Research, Beam backgrounds and Software R&D:** 2023 - Present: I lead and perform studies of beam backgrounds, e^+e^- pair-production and hadron-photoproduction, at the Cool Copper Collider, 10 TeV plasma wakefield accelerators, and FCCee in the US. FCCee is the current focus. I also lead the development of future collider software in the context of applying columnar analysis and advanced processing frameworks to the expected collider data.
- **LPC Workshop Series on Effective Field Theories:** (2023 - present) I work with multiple LPC Distinguished Researchers and FNAL staff to organize this series of workshops. I contribute by helping to bring in engaging speakers for students during the hackathon sessions, and making sure we cover major discussions and critical points evolving on the experimental side of EFT research. I have helped with all EFT workshops thus far (at FNAL and Notre Dame), with more engagement starting from the Notre Dame workshop.
- ***smartpixels*:** (2023 - present) I lead the development of next generation smart frontends for pixel detectors. We have developed filtering and regression algorithms for pixel clusters that make pixel detector information feasible to introduce to the CMS L1 trigger at HL-LHC. We are pursuing testing and development of prototype readout chips with ML algorithms that process patches of pixels in real time, providing the ability to compress and filter cluster data. We are investigating extensions to other detector types.

- **Boosted Higgs Final States:** (2020 - present) I worked with postdocs and students to help design and evaluate heavy flavor selection strategies for a search for boosted Higgs decays to Hcc. I also helped evaluate analysis design and final fitting in the search for VBF production of Boosted Hbb. These analyses are novel searches for high-p_T Higgs boson production in hadronic final states. Once at SM precision during HL-LHC understanding the ratio of the charm and bottom Yukawa couplings can be a powerful constraint on new physics. Similarly, in HL-LHC the boosted VBF production mode is a sensitive test of Electroweak Physics at very high energies as well as a powerful final state in searches for EFT effects.
- **Graph Neural Networks for Reconstruction:** (2019 - present) I am leading a team of 10 researchers to understand and apply the novel algorithms made possible by machine learning using convolutions on graphs. So far this technique has been immediately applicable to tracking and calorimetry in general and the algorithms are being scaled to function in the high-pileup environment of the HL-LHC. A major goal of this effort is to eventually develop a particle-flow reconstruction based on graph learning techniques.
- **Coffea and Big Data Technologies in HEP Analysis:** (2019 - present) I am the project leader of the Columnar Object Framework For Effective Analysis (Coffea) which has O(100) users and several years worth of published papers. We have employed multiple tools from the scientific python ecosystem and industry standard big-data platforms like Apache Spark and found that it is possible to significantly improve the typical physics analysis workflow with them. In particular, we have focused on interoperability between various technologies and making these tools accessible to physicists in an intuitive fashion. We achieve a factor 1000x speedup over the prior interpreter-bound pyROOT-based analysis workflows and have equivalent throughput to ROOT's RDataFrame. Explorations into GPU acceleration offer possibilities of further speedup by a factor of 40-50 with little changes to user code.
- **MIP Timing Detector Project:** (2017 - 2019) Following the precision timing research below, a sub-detector concept was developed and submitted to the CMS Collaboration for review and approval. The detector concept was reviewed positively and approved, resulting in a call for the formation of a project within CMS. The project has submitted its TDR and is approved to be constructed for the CMS Phase 2 ugprades.
- **Precision Timing Research:** (2016 - 2017) I led a team of 30 researchers to understand the usefulness of fast-timing detectors in calorimetry and tracking, with resolutions O(30 ps), in the context of mitigating of large amount of overlapping proton-proton collisions at the HL-LHC. The group, under my leadership, has been able to demonstrate the effectiveness of this detector for every physics object used in CMS analysis, and a reference detector has been approved within CMS towards the formation of a project. In particular, I study the use and implementation of a "precision timing layer" that can time-stamp minimum ionizing particles, allowing the times of interaction vertices to be measured. Studies resulting from this research were used to promote and develop the MIP Timing Detector, which is now a phase 2 upgrade project on the CMS experiment.
- **Blockchain and Cryptography for HEP Computing:** (2019) As an independent research project I explored the possible uses of blockchain and related cryptographic methodologies to expand the computing resources available during the HL-LHC, which will be demanding on both computing and storage resources. I collected and evaluated existing technologies, products, and ongoing lines of research to understand if this is a viable option and how it might be implemented or used by the HEP community. While this was an untapped direction for HEP computing there were not many viable technologies, as it was a young field. Applications in long term data storage were discussed, but not pursued.
- **Search for high mass resonances decaying into Z(qq) + γ:** (2015-2017) In light of the diphoton excess at 750 GeV found in 2015, enhanced Zγ production is a natural channel in which to search for a corresponding excess. In order to gain in branching fraction, a merged-jet analysis was considered in addition to the usual leptonic search. In this ongoing analysis I am working on ensuring background estimation does not have significant bias, I help to optimize the analysis categorization, and I orchestrated the combination between the hadronic and leptonic Z boson decay channels.

- **High Granularity Calorimeter Reconstruction:** (2015 - present) I led the effort on CMS to develop novel, purpose specific algorithms for use in the Phase 2 High Granularity Calorimeter (HGCal). The reconstruction I developed during the studies of the CMS Phase 2 Technical Proposal and Scope Document were key components to making the physics case, and now further refinements are necessary. The focii of the project are to understand the capabilities of the calorimeter itself, including an intrinsic fast timing capability, and to integrate the output of HGCal into CMS through using Particle Flow techniques.
- **Model-independent search for new physics via self-interaction of electroweak bosons:** (2015 - 2016) I lead the effort in CMS, in collaboration with two postdocs and the CMS Higgs combination group, toward combining multi-boson production data with Higgs data to analyze the electroweak sector in the context of an effective field theory. In response to the discovery of a light Higgs boson at a mass of 125 GeV, the study of generalized anomalous interactions between gauge boson in the electroweak sector has been revisited by the theory community to use modern theoretical techniques. These modern theories include anomalous couplings to the Higgs boson as well as the other gauge bosons. Furthermore, all of these couplings are related through electroweak gauge invariance, creating a unique and powerful description of possible extensions to the electroweak sector.

Post Graduate

This work was done under the supervision of Dr. Jeffrey Berryhill at Fermilab and CERN.

- **Search for a light Higgs Boson Decaying to Z + γ Final State:** I developed a stable background model using gaussian convolutions of polynomial basis functions to describe the continuum background in the search for this decay of the Higgs boson. This project also involved implementing a systematic way of removing events that are kinematically consistent with radiative decays of the Z boson to two muons and a photon which removed photon energy scale dependent variations in the fitting regions used for the analysis.
- **Global Event Description e-γ Integration:** I led the effort, in collaboration with the 2013 e-γ Physics Object Group convenership, to re-work electron and photon reconstruction and identification in the context of the Global Event Description (GED, formerly "Particle Flow"). The majority of this work is aimed at merging the common steps of electron and photon reconstruction. This minimizes redundant processing and benefits from having a well understood and maintainable reconstruction codebase. I am the main developer of the code that determines the most correct energy flow for electrons and photons within the GED algorithm. In particular, I developed the association of ECAL energy deposits (clusters) and tracks from electrons, photon conversions, or converted Bremsstrahlung photons. This process called "refined-superclustering" is important in the GED algorithm as it protects against double counting of energy in the event. The integration of the electron and photon reconstruction within the GED algorithm therefore also has an important impact on CMS jet reconstruction and missing transverse energy determination.
- **Phase 2 Upgrade Reconstruction Development:** I integrated both major CMS Phase 2 upgrade design concepts, the "Shashlik + HE Rebuild" and "High Granularity Calorimeter" (HGC) options, into the CMS reconstruction. This required development of novel clustering algorithms due to the complex design of the HGC and the harsh environment of the SLHC.
- **Dynamic ECAL Clustering Algorithm Development:** I led studies to develop and improve an ECAL energy clustering algorithm which dynamically adjusts the physical extent of the set of clusters considered as a single object, a "SuperCluster". This algorithm is based on using the energies of those sub-clusters as well as the geometry of CMS. The newly developed clustering algorithm has the benefit of being robust against pileup while retaining good containment of electromagnetic showers. The energy response and energy resolution of photons and electrons thus stabilize with respect to increasing pileup interactions. This algorithm is the primary ECAL superclustering algorithm for the 2015 run.

- **Global Event Description Core Algorithm Development:** I am a lead developer for the redesign of the CMS particle flow reconstruction to be used in the 2015 LHC run and CMS upgrade studies. The first phase of the resdesign involves abstraction of the various stages of Particle Flow reconstruction so that the algorithm is independent of the underlying detector design and available data. The necessary code refactoring is complete and has lead to the rapid deployment of novel clustering algorithms for Run2 and the Phase2 upgrades. The second phase is in progress and involves physics performance improvements as well as upgraded-detector feasibility studies and characterization.
- **Organization of Photon Fake Rate Measurements:** I organize and work with colleagues to study the production rates of jets that are reconstructed as well-identified photons in CMS physics analyses. The main goal of this effort is to determine a common set of techniques to estimate the jet-to-photon fake rate and centralize the tools to do calculate these estimates within the e-γ Physics Object Group.
- **Organization of Photon ID Performance Information for 2012:** I collaborated with scientists from multiple institutions to collate the main set of selection criteria used for photon ID in CMS. This included an exhaustive data-to-monte-carlo comparison of the inputs to the multivariate analysis-based photon ID used in the search for the decay of the Higgs boson to two photons and of the cut-based photon ID used in other CMS analyses. Under my coordination new photon performance plots were approved in March 2013 with the full 2012 Run 1 data.
- **Implementation and Organization of Muon Trigger Upgrade Study Framework:** I developed and maintain a framework for performing studies of and developing emulators for the upgraded CMS muon trigger system. A key feature of this frame work is being able to access multiple trigger primitive types in a uniform way, facilitating studies of the foreseen inter-subsystem muon track-finders. Additionally, it was developed to be modular and easily extended to include new data from additional subsystems, allowing for quick studies of various transverse momentum assignment or track finding algorithms. This framework is currently used by four other institutions pursuing studies of DT-RPC hit merging, studies HO trigger primitive information, inter-subsystem track-finding and upgrade transverse momentum assignment studies.
- **Common Isolation Framework for Physics Objects:** I am developing a common isolation framework for physics objects to improve consistency and reproducibility of analysis. This framework will be adopted by all physics object groups that manage isolated objects on CMS.
- **"miniRECO" Fast Reprocessing Development:** I am lead developer on a project to improve the CMS reprocessing time by removing the need to reprocess tracking, which is needed less frequently than reprocessing of the calorimetry. The goal of this project is to speed up the CMS reprocessing time by a factor of five, reducing the reprocessing time to one week. This will drastically improve the turn-around time in analyses that require constantly up-to-date calibration data, as in measurements of the H$\rightarrow \gamma\gamma$ and H$\rightarrow$ZZ$\rightarrow 4\ell$ final states.

Selected Workshops and Conferences

- Fermilab Wine & Cheese, 'Intelligent Detector Systems', 2025
- Invited Talk, 'Effective Field Theory Prospects at Future Colliders', LPC Workshop on EFTs, 2025
- Invited Talk, 'Smart Pixel Project: AI for Pixel Readout', ML4EIC, 2025
- Session Chair, Higgs Physics at Future Colliders, Higgs 2025
- Invited Talk, 'Application to Colliders: Smart Pixels', ML4FE Workshop, 2025
- Submitted Talk, 'Beam-Induced Background Simulation Studies for the Cool Copper Collider', 3$^{\text{rd}}$ ECFA Workshop on Future e^+e^- Colliders, 2024
- Submitted Talk, 'Columnar Analysis for Lepton Colliders using Coffea', LCWS, 2023

- Submitted Talk, 'Collider Background Studies', LCWS 2023
- Submitted Talk, 'Out-of-Time Pileup Mixing for the C3 Collider Concept', 2nd ECFA Workshop on Future e^+e^- Colliders, 2023
- Organization Committee Member, LPC Workshop Series on EFTs, 2023-present
- Organization Committee Member, Multiboson Interactions Workshop, 2014-2021
- Session chair, 'X18: Electroweak and Standard Model Physics II', APS April Meeting, 2021
- Invited talk, 'Artificial intelligence for tracking', 4th FCC Workshop November 2020
- Parallel talk, 'Modern ML Tools for Event Reconstruction', APS April Meeting 2020
- Multiple submissions related to Coffea, PyHEP 2020
- Plenary talk, 'Coffea', PyHEP 2019
- Plenary talk, 'Rare Higgs Decays and Production Modes', Rencontres de Blois, 2019
- Plenary talk, 'Blockchain for Large Scale Scientific Computing', CHEP, 2018
- Invited talk, 'Proposed Timing Detectors for ATLAS and CMS', ACES Workshop on ATLAS and CMS Electronics, 2018
- Invited talk, 'The Timing Frontier - Timing Layers at ATLAS and CMS', APS April Meeting 2018
- Invited talk, 'First Steps Towards Four-Dimensional Tracking: Timing Layers at the HL-LHC', Connecting The Dots 2018
- Invited talk, '4 Dimensional Trackers', Connecting The Dots / Workshop on Intelligent Trackers, 2017
- Presented talk, 'Challenges of Particle Flow reconstruction in the CMS High-Granularity Calorimeter at the High-Luminosity LHC', ICHEP, 2016
- Presented poster, 'Concepts and design of the CMS High Granularity Calorimeter Level 1 Trigger', ICHEP, 2016
- Invited talk, 'Picosecond Timing: Applications and Technologies Towards Mitigating the Effects of High-Pileup', ACES Workshop on ATLAS and CMS Electronics, 2016
- Presented talk, 'Forward Detector Performance at the HL-LHC', ECFA High Luminosity LHC Experiments Workshop, 2014
- Presented talk, 'Challenges of Particle Reconstruction in Hadronic Environments', 10^{th} Rencontres du Vietnam "Physics at LHC and Beyond", 2014
- Presented talk, 'Other SM measurements: Boson + jets and diboson production at ATLAS and CMS' at the 49^{th}Rencontres de Moriond on "EW Interactions and Unified Theories", 2014
- Presented poster, 'Measurement of WW, Wγ and Zγ Cross Sections and Limits on Charged and Neutral Anomalous Triple Gauge Couplings at CMS' at PANIC11: 19^{th} Particles and Nuclei International Conference, 2011
- Presented talk, 'J/ψ polarization in pp collisions at $\sqrt{s}$= 7 TeV' at Quarkonium Production: Probing QCD at the LHC, 2011

Awards

- CMS 2020 Young Researcher Prize, for 'His crucial and sustained contribution to the physics justification, the design, and the approval of the MIP Timing Detector (MTD)', and for his performance studies of the high granularity endcap calorimeter.
- CMS 2014 Achievement Award, for 'his leading role in the software developments of the Flow reconstruction with the new upgrade Endcap Calorimeter concepts and for the optimisation of the eγ software for performance studies.'

Last updated: August 14, 2026