ANDRE FRANKENTHAL

afrankenthal@gmail.com • https://frankenthal.dev
Jadwin Hall, Princeton University, Princeton, NJ 08544

EDUCATION

Cornell University *(2013 – 2020)*
Ph.D., Physics, 2020
M.S., Physics, 2017
Thesis: "*Search for Dark Matter Decaying to Two Displaced Muons Produced in Proton-Proton Collisions at 13 TeV with the CMS Detector, and for Dark Photons Produced in Electron-Positron Fixed-Target Collisions at 500 MeV with the PADME Detector*"
Advisor: Prof. Jim Alexander

Reed College *(2009 – 2013)*
Phi Beta Kappa, dean's list equivalent all years
B.A., Physics, 2013
Senior thesis: "*The Quantum-Mechanical Dynamics of a Particle in the Anti-de-Sitter Space Central Potential*"
Advisor: Prof. Nelia Mann

PROFESSIONAL BACKGROUND

Associate Research Scholar / Dicke Fellow in the Physics department at Princeton University, Princeton, NJ *(2020 – present)*

SELECTED RESEARCH AND WORK EXPERIENCE

Observation of the rare $\eta \to 4\mu$ decay with scouting in CMS. Use the scouting dataset in CMS to study rare meson decays of the η meson. Developed specialized hadronic Monte Carlo generator to interface with the CMS software and produce samples of very rare meson decays not available elsewhere. *(2021 – present)*

PADME reconstruction software for new tagging detector. Wrote reconstruction software for the new ETagger detector of PADME, with the goal of distinguishing photon from charged lepton calorimeter energy deposits. (2022 – present)

Displaced tau lepton reconstruction in CMS. Lead a project with a Princeton graduate student to improve the reconstruction and identification of displaced taus in CMS by leveraging graph neural networks. The benchmark model we study is a semi-leptonic di-tau decay topology produced from gauge-mediated supersymmetry breaking (GMSB), which currently has a large experimental gap in coverage. Ultimately this could also be applied in a search for inelastic dark matter in the tau channel. *(2021 – present)*

Physics analysis management. Co-contact for the long-lived data format taskforce in the Exotica Physics Analysis Group (PAG) at CMS *(2021 – present)*
- Collect and organize the data needs of the long-lived group in CMS
- Investigate data availability for the next data-taking run of the LHC

- Support physics analyzers by coordinating efforts to ensure the large dataset collected by CMS is available to them for physics processing

Physics object management. Co-convener of the Calibration subgroup in the Muon Physics Object Group (POG) at CMS *(2020 – 2022)*
- Organize and prepare first performance paper on displaced muons, to be submitted in late 2022
- Manage and develop a new tag-and-probe framework for measuring muon efficiencies and scale factors with Apache Spark and Apache Parquet backends
- Prepare tutorials to introduce users and analyzers to the platform, and support and advise them throughout their analyses
- Maintain an updated set of official muon-related scale factors for the Collaboration
- Coordinate several parallel developments of the framework, and supervise progress among developers while providing support where needed

CMS outer tracker phase-2 upgrade – module testing and characterization. Implement test system at Princeton for silicon strip sensors as part of the next-phase upgrade of the CMS Outer Tracker detector to cope with the upcoming High Luminosity LHC (HL-LHC). The new sensor modules are tested to ascertain parameters like resolution performance, thermal behavior, background noise levels, and power requirements *(2021 – present)*

Search for inelastic dark matter with muons. Pioneered a search for inelastic dark matter at CMS using displaced muon signatures *(2018 – 2023)*
- Built the analysis framework from the ground up, in both C++ and Python/Jupyter notebooks
- Generated Monte Carlo signal samples (using Madgraph for the hard scattering and Pythia 8 for shower and hadronization) with large displacements
- Studied trigger and signal object reconstruction efficiencies, and designed event and object selection based on generated signal and background simulation samples
- Developed the data-driven background estimation method
- Made limit plots for sensitivity projections and estimates
- Wrote paper, to be submitted to *Phys. Rev. Lett.*

Search for self-interacting dark matter. First search for self-interacting dark matter at a collider, using collimated and displaced lepton jets. Coordinate and advise students on search strategy, guiding them through analysis workflow, trigger and reconstruction issues, and limit setting procedures. (2019 – present)

Reconstruction and analysis of PADME data. Contribute to and advise the reconstruction effort of the PADME experiment data, collected at the Laboratori Nazionali di Frascati (LNF), in Italy *(2018 – present)*
- Created prototype of a template-derived pulse fit procedure of electromagnetic calorimeter signals to extract energy and hit time of multi-particle pulses arriving closely in time
- Advise other members of the Collaboration (about 15 people) on writing robust reconstruction software for the different sub-detectors
- Design a search for inelastic dark matter inside the PADME data

Detector characterization of PADME's small-angle calorimeter. Characterized the performance of the Small-Angle Calorimeter (SAC) in the PADME experiment, in Frascati, Italy *(2017 – 2018)*
- Collected test beam data with a prototype of the detector at LNF
- Performed analysis of the data, assessing detector characteristics such as energy and time resolution, and peak separation capabilities

- Simulated the optical physics inside the PbF2 crystals with the Geant4 MC toolkit, to compare against the data and extract insights
- Wrote a paper with the results of the characterization, published in *NIM A*

CMS inner tracker phase-2 upgrade -- pixel test beam. Leading role in the US-CMS test beam team assessing the performance of R&D sensors for the next upgrade of the LHC *(2017 – 2020)*
- Critical role to ensure the continuing success of the test beam effort 24/7 during our assigned weeks-long slots
- Installed, adapted, and debugged hardware needed to acquire test beam data
- Wrote software for analysis of the collected data
- Performed analysis of both non-irradiated and irradiated small-pitch sensors (pitches 25x100 μm^2 and 50x50 μm^2, and readout chips PSI46, PROC600, and RD53A) to compare performance and radiation hardness (e.g., pixel hit resolution, efficiency, and charge collection)
- Presented periodic progress reports to CMS sensor and management meetings
- Developed tutorial sessions to train about 20 other students, postdocs, and faculty on how to perform analysis of test beam data

CMS inner tracker phase-2 upgrade -- simulations. Physics simulation of prototypes for the Phase 2 Inner Tracker upgrade *(2017 – 2020)*
- Performed parameterized (using the tkLayout software) and full Geant4-based Monte Carlo simulations of prototypes developed by the mechanical engineering team at Cornell
- Assessed the physics performance impact of different mechanics and thermal choices, and helped optimize the design with feedback from simulations
- Wrote code to improve the realism of the simulations compared to the prototypes

FPGA development and MMAPS calorimeter test beam. Firmware development for custom digitizer used in the MMAPS calorimeter prototype, followed by test beam at LNF to evaluate performance (2016)
- Wrote Verilog firmware for the FPGA (Xilinx Zynq) in the digitizer
- Assessed and optimized data throughput rate
- Assembled the calorimeter prototype with digitizer, crystals, and PMTs
- Collected and analyzed physics data from the prototype with a test beam at LNF, Italy

Control and monitoring system for the Muon g-2 kicker. Developed from the ground up a control and monitoring system for the Muon g-2 kicker at Fermilab, using System on a chip (SoC) boards like Arduino and Intel Galileo, and including a web server with JavaScript handling of real-time control and monitoring information *(2015 – 2016)*

Kalman filter for Muon g-2 trackers. Implemented a Kalman Filter in C++ for use with the Muon g-2 straw trackers. The filter takes straw hits and the magnetic field around the storage ring as input to reconstruct the path of decay positrons through the tracker *(2013 – 2014)*

Test beam characterization of Muon g-2 calorimeter. Contributed to the test beam effort at SLAC to characterize the Cherenkov-based lead fluoride (PbF_2) calorimeters used in the Muon g-2 experiment, published in NIM A. Wrote Geant4-based Monte Carlo simulations of the crystals to compare results against test beam data, and played critical role in the development and debugging of the DAQ system *(2014)*

Optical Monte Carlo simulation of Muon g-2 calorimeter. Wrote a Geant4-based Monte Carlo simulation to understand the optical physics processes inside the Muon g-2 calorimeter and the expected performance of the detector in real-world conditions *(2013 – 2014)*

PMT R&D at EDELWEISS. Wrote control and monitoring software for PMTs in the EDELWEISS experiment, which searches for direct evidence of dark matter. With software system, studied the single photo-electron behavior of the PMTs to be deployed in the next generation of the experiment, EUREKA *(2012)*

HONORS AND AWARDS

Princeton Robert H. Dicke Fellowship *(2020 – present)*

Fermilab LPC Guests & Visitors Award *(2018 – 2019)*

Graduate Resident Fellow *(2018 – 2020)*

Cornell Albert Silverman Memorial Award *(2018)*

URA Visiting Scholars Program Award, declined *(2016)*

Excellence in Physics Teaching Award, Physics 1101 *(2013)*

Reed College Commendation for Excellence in Scholarship *(2009 – 2013)*

Brazilian University Entrance Exams, first of thousands of applicants at CEFET *(2009)*

Three silver medals in the Brazilian Programming Olympiad *(2006 – 2009)*

TEACHING AND OUTREACH

ParticleBites. Writer and contributor to ParticleBites, a blog dedicated to explaining recent particle phyiscs results to a lay audience *(2019 – present)*

Fuertes Observatory. Give lectures and engage students at the Fuertes Observatory on the Cornell campus *(2019 – 2020)*

HEPMAP. Developing an educational website to introduce the public to the different ongoing high-energy physics experiments worldwide *(2019 – present)*

Arduino Series. Created short introductory Arduino courses for Cornell undergraduate students highlighting both practical and fun applications of the Arduino stack; meant for students with no prior programming experience *(2018 – 2020)*

Undergraduate resident advising. Resident advisor of over 150 undergraduate students at Cornell *(2018 – 2020)*

Physics Teaching. Teaching Assistant in Physics at Cornell *(2013 – 2017)*. Introductory physics for physics majors; Introductory physics for non-majors; Electronics laboratory; Computational physics (grader); Standard model of particle physics (grader)

Math Tutoring. Math tutor at the Reed College Tutoring Center *(2011 – 2012)*

Physics Grading and Tutoring. Physics grader and tutor at the Reed College Physics department *(2011 – 2013)*

SELECTED PUBLICATIONS

For all publications, please see https://inspirehep.net/author/profile/A.Frankenthal.1

CMS Collaboration, "*Search for inelastic dark matter in events with two displaced muons and missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13\ TeV$*," arXiv:2305.11649 [hep-ex]. Under review in Phys. Rev. Lett.

CMS Collaboration, "*Observation of the rare decay of the η meson to four muons*," arXiv:2305.04904 [hep-ex]. Under review in Phys. Rev. Lett.

D. S. M. Alves et al., "*Shedding light on X17: community report,*" Eur. Phys. J. C 83 (2023) 230

PADME Collaboration, F. Bossi et al., "*Cross-section measurement of two-photon in-flight annihilation of positrons at $\sqrt{s}=20\ MeV$ with the PADME detector,*" Phys. Rev. D 107 (2023) 012008, arXiv:2210.14603

PADME Collaboration, "*The PADME beam line Monte Carlo simulation,*" J. High Energ. Phys. 2022 (2022) 233, arXiv:2204.05616

PADME Collaboration, P. Albicocco et al., "Commissioning of the PADME experiment with a positron beam," J. Instrum. 17 (2022) P08032, arXiv:2205.0343

PADME Collaboration, A. Frankenthal, "*Searching for Dark Photons with PADME*", arXiv:1910.00764.

A. Frankenthal, J. Alexander, et al., "*Characterization and Performance of PADME's Cherenkov-Based Small-Angle Calorimeter*", NIM A, 919 (2019), 89-97.

L. P. Alonzi, et al., "*The calorimeter system of the new muon g -2 experiment at Fermilab*", NIM A, 824 (2016), 718-720.

A.T. Fienberg, L.P. Alonzi, A. Anastasi, R. Bjorkquist, D. Cauz, R. Fatemi, C. Ferrari, A. Fioretti, A. Frankenthal, et al., *"Studies of an array of PbF2 Cherenkov crystals with large-area SiPM readout",* NIM A, 783 (2015), 12-21.

J. Grange et al. Muon g-2 Collaboration, "*Muon (g-2) Technical Design Report*", arXiv:1501.06858.

SERVICE AND COMMITTEE WORK

Referee for Physics Letters B (2022 – present)

Referee for Progress of Theoretical and Experimental Physics (2021 – present)

Referee for Journal of Instrumentation (2020 – present)

"Dark Cosmos" joint theory-experiment committee for Princeton's Physics Department (2022 – present)

Local organizing committee for the *"Shedding light on X17"* workshop at LNF (2021)

Colloquium committee for Cornell's Physics Department (2015 – 2017)

SELECTED SEMINAR, WORKSHOP, AND CONFERENCE TALKS

"*The Piper at the Gates of Dome: Probing low-mass new physics with the CMS data scouting and parking pipelines*" Fermilab Wine & Cheese Seminar. July 28, 2023 (forthcoming). **Fermilab**. Batavia, IL, USA.

"Probing low-mass physics with high-energy accelerators" Physics Seminar. April 13, 2023. **Boston University**, Boston, MA, USA.

"*First results of the PADME Experiment and near-term plans*" UCLA Dark Matter 2023. March 30, 2023. **University of California, Los Angeles**. Los Angeles, CA, USA.

"*First search for inelastic dark matter at the LHC with the CMS detector*" UCLA Dark Matter 2023. March 30, 2023. **University of California, Los Angeles**. Los Angeles, CA, USA.

"*Search for BSM Physics in CMS*" LISHEP 2023. March 6, 2023. **State University of Rio de Janeiro**. Rio de Janeiro, RJ, Brazil.

"Dark Matter Studies with the PADME Experiment" PPC 2022: XV International Conference on Interconnections between Particle Physics and Cosmology. June 7, 2022. **Washington University in St. Louis**, St. Louis, MO, USA.

"Computing tag-and-probe efficiencies with Apache Spark and Apache Parquet." PyHEP 2021. July 5, 2021. **Virtual**.

"The Hidden World of Dark Matter." SSO Seminar. November 20, 2019. **Oregon State University**, Corvallis, OR, USA.

"Dark Matter in the Lab: Searching for Dark Sector Physics with Accelerators." Physics of the Universe Seminar. November 19, 2019. **University of Oregon**, Eugene, OR, USA.

"The Dark Side of the Force: Searching for Dark Sector Physics with Colliders and Fixed-Target Experiments." TRIUMF Special Seminar. November 18, 2019. **TRIUMF,** Vancouver, BC, Canada.

"A Bridge Between Two Worlds: Dark Photons in the Lab." Reed College Seminar. November 13, 2019. **Reed College**, Portland, OR, USA.

"Dark Matter in the Lab: Searching for the Dark Sector with Accelerators." Cornell Physics Department Lunch Talk. September 30, 2019. **Cornell University**, Ithaca, NY, USA.

"How to Search for Dark Matter." Fuertes Observatory Lecture Series. September 13, 2019. **Cornell University**, Ithaca, NY, USA.

"Search for Inelastic Dark Matter with the CMS Detector." Oral presentation. Dark Matter at the LHC 2019. August 13-16, 2019. **University of Washington**, Seattle, WA, USA.

"Searching for Dark Photons with PADME." Oral presentation. 2019 Meeting of the Division of Particles and Fields of the American Physical Society. July 29 – August 2, 2019. **Northeastern University**, Boston, MA, USA.

"Search for Dark Photons with CMS and Fixed-Target Experiments." Oral presentation. New Perspectives 2019. June 10-11, 2019. **Fermilab**, Batavia, IL, USA.

"The Dark Side of the Force: Searching for Dark Sector Physics." Weekly Colloquium. April 18, 2019. **Union College**, Schenectady, NY, USA.

"Thesis Seminar", Reed College Physics Colloquium. April 2013. **Reed College**, Portland, OR, USA.

STUDENT CO-SUPERVISION AND MENTORING

Graduate students:
- Gage DeZoort (Princeton). Search for pseudoscalars in a->ZH events (2021 – present)
- Sam Higginbotham (Princeton). Search for pseudoscalars in H->aa->2mu2e (2022 – present)
- Bennett Greenberg (Princeton). Outer Tracker Phase 2 upgrade project (2021 – present)
- Joaquin Castaneda (Nebraska). Search for self-interacting dark matter (2020 – present)
- Sam Bright-Tonney (Cornell). Search for inelastic dark matter (2020 – present)
- Tres Reid (Cornell). Search for inelastic dark matter (2018 – 2021)

Undergraduate students:
- Natasha Greenstein (Princeton). Studies of bilepton models (2023 – present)
- Kasia Krzyzanska (Princeton). Studies of rare eta meson decays (2021 – 2022)
- Aditi Kabra (Cornell). PADME data reconstruction (2017 – 2019)
- Neil Minet (Cornell). CMS pixel thermal studies (2018 – 2020)
- Arthur Campello (Cornell). CMS pixel thermal studies and MMAPS accelerator studies (2018 – 2020)
- Kyle Fitzgerald (Cornell). CMS pixel mechanics simulation studies (2018 – 2019)
- Connor Daly (Cornell). Muon g-2 DAQ development and testing (2013 – 2014)

SCHOOLS AND OTHER WORSKHOPS ATTENDED

Computational and Data Science for High-Energy Physics (CoDaS-HEP) Summer School. July 22-26, 2019. Princeton University, Princeton, NJ, USA.

Current Trends in Particle Theory III. June 16, 2019. University of Illinois at Chicago, Chicago, IL, USA.

CMS Data Analysis School at the LPC. January 8-12, 2018. Fermilab, Batavia, IL, USA.

Future of Collider Searches for Dark Matter. July 27-28, 2017. Fermilab, Batavia, IL, USA.

International School of Trigger and Data Acquisition (ISOTDAQ). January 28 – February 5, 2015. Brazilian Center for Research in Physics, Rio de Janeiro, RJ, Brazil.

Raya Cowan ORT International Summer School. August 2008. WIS Plasma Lab, Weizmann Institute of Science, Rehovot, Israel.