

# Abhijith Gandrakota

Fermilab, Pine st,  
Batavia, IL - 60510  
✉ [abhijith@fnal.gov](mailto:abhijith@fnal.gov)

## Employment

- 2025-present **Wilson Fellow / Associate Scientist**, *Fermi National Accelerator Laboratory*, Batavia, USA.  
2021-2025 **Postdoctoral Research Associate**, *Fermi National Accelerator Laboratory*, Batavia, USA.

## Education

- 2015-2021 **PhD in Physics**, *Rutgers University*, New Brunswick, USA.  
2010-2015 **Integrated BS-MS**, *Indian Institute of science Education and Research*, Pune, India.

## Selected Awards and Grants

- **Lead-PI on Fermilab LDRD award** for *Efficient Transformers and Foundation models on FPGA*
- Scientific lead on American Science Cloud project *Hunting for TREASURE*; Part of DOE Genesis mission
- **Distinguished Researcher (DR) fellowship** awarded by *Fermilab LHC physics Center*
- **ALCF Director's Discretionary (DD) allocation award** for GPU node-hrs on Polaris Supercomputer
- **Samuel Marateck Fellowship in QFT physics** for the year 2019
- Recipient of **INSPIRE fellowship (2010-2015)** awarded by **Dept. of Science and Technology, India**

## Research Experience

### Low mass di-tau resonances with data scouting.

- Analysis targeting low mass scalars decaying to di-tau resonances using Run-3 data scouting.
- Developed custom tau reconstruction identification algorithms for targeting low  $p_T$  hadronic tau reconstruction.
- Preliminary detection of a upsilon to di-tau decay at hadron collider (**CMS NOTE-2024/006**). Search in progress.

### Higgs initiated Dark Showers.

- Targeting perturbative hidden valley theories coupling to standard model through Higgs.
- Generalised search primarily targeting prompt decays without missing energy using out of distribution detection.
- Working on a preliminary analysis on data collected in LHC Run-2 and Run-3.

### Search for pair produced three-jet resonances at LHC.

- Lead author of this search for resolved multijet resonances. First analysis to use Particle-Flow scouting datasets.
- Set the most stringent limits till date (**arXiv:1810.10092**, **arXiv:2404.02992**).
- Extrapolating to generalised multijet resonances search with Machine Learning (ML) using CMS Run-3 data.

### Search for boosted multijet resonance with Particle Flow Scouting.

- Lead analyzer on a search targeting boosted multi-jet BSM signatures, using the Particle-Flow Scouting dataset.
- Developed a framework to reconstruct large-R jets with scouting inputs and implemented substructure techniques.
- Most sensitive boosted multijet analysis, first ever limits on RPV Higgsinos (**arXiv:2404.02992**).

### Ultra low mass long-lived di-muon resonances.

- Analysis targeting long lived di-muon resonances at the sub GeV range, looking for scalars and exotic B decays.
- One of the most sensitive searches in displaced dimuon phase space (**arXiv:2112.13769**).
- Published a pheno study looking at HL-LHC prospects (**arXiv:2008.06918**).

## AI/ML **Efficient ML for real-time AI.**

- Developing efficient neural network techniques and transformers for ultra fast inference on chips (FPGAs).
- Published efficient architectures ([arXiv:2311.17162](#)) and model compression techniques ([arXiv:2311.14160](#)).
- Awarded LDRD (\$356k) for development of efficient transformers for L1 Trigger and quench detection applications.

## **Robust Representation learning.**

- Semi-supervised ML algorithms for nuisance invariant representation learning ([arXiv:2401.08777](#)).
- Demonstrated to have leading performance in unsupervised tasks while decorrelated to kinematic features.
- Adapting this techniques to search for Higgs initiated dark showers.

## **Gaussian processes regression for background estimation.**

- Pioneered framework to use Gaussian process regression for fitting and background estimation of LHC data.
- Developed procedures for model selection in Gaussian process regression. Designed a new kernel to fit signal shapes.
- Paper outlining these procedures is published ([arXiv:2202.05856](#)).

## Hardware **Anomaly Detection for CMS Level-1 Trigger.**

- Project lead for developing a new ML based anomaly detection trigger for CMS L1 trigger. ([CMS-DP-2023-079](#)).
- $\mathcal{O}(10)$ x more performant than current rule based trigger algorithms.
- Implemented in CMS trigger system, collecting data since 2024.

## **Extended hybrid tracking at Level-1 in CMS Phase-2 for HL-LHC.**

- Working in L1 Tracking group to extend the CMS baseline tracking for HL-LHC, to reconstruct displaced tracks.
- Significantly extended the current baseline tracking to efficiently reconstruct tracks up to  $|d_0| > 5$  cm.
- The results are presented in [CMS-TDR-021](#).

## **Track jets and displaced jet triggers at Level-1 for HL-LHC.**

- Worked on developing FPGA friendly algorithm to cluster track jets at L1, with selection to identify displaced jets.
- Co-developer for L1 track triggers sensitive to detect exotic Higgs decays with long lifetime.
- Found improvement in sensitivity close to 10X. Results outlined in [CMS-PAS-FTR-18-018](#), [CMS-TDR-021](#).

## **Neural Network based energy regression for HCAL (DLPHIN).**

- Created a neural network architecture for energy regression in HCAL. Outperformed traditional alternates.
- Designed a custom " $\chi^2$  loss function" based on HCAL photon statistics, aiding in greater stability of performance.

---

## Leadership

- Convener for Jets+X sub group for Exotic BSM physics in CMS [2022-2024]
- Convener of Machine Learning innovation group in CMS [2025-2027]
- LHC Physics Center events committee co-chair [2024-]
- Fermilab lab-wide AI meeting coordinator

---

## Selected Publications (major contribution)

### **RINO: Renormalization Group Invariance with No Labels.**

arXiv:2509.07486, Spotlight contribution in ML for Physical Sciences, NeurIPS 2025

### **An Evaluation of Representation Learning Methods in Particle Physics Foundation Models.**

arXiv:2511.12829, Accepted in ML for Physical Sciences, NeurIPS 2025

### **Why is Attention Sparse in Particle Transformer?.**

arXiv:2512.00210, Accepted in ML for Physical Sciences, NeurIPS 2025

### **Sub-microsecond Transformers for Jet Tagging on FPGAs.**

arXiv:2510.24784, Accepted in ML for Physical Sciences, NeurIPS 2025

**Spatially Aware Linear Transformer (SAL-T) for Particle Jet Tagging.**

arXiv:2510.23641, to be submitted to SciPost

**Search for a low mass resonance decaying to  $\tau\tau$  using data collected with a dedicated high-rate data stream.**

CMS-PAS-EXO-24-012, To be submitted to PRL

**Interpreting Transformers for Jet Tagging.**

arXiv:2412.03673, Accepted in ML for Physical Sciences, NeurIPS 2024

**Real-time Anomaly Detection at the L1 Trigger of CMS Experiment.**

arXiv:2411.19506, Proceedings for ICHEP 2024

**Population-level Dark Energy Constraints from Strong Gravitational Lensing using Simulation-Based Inference.**

arXiv:2407.17292, Accepted in AI for science, ICML 2024

**Enriching the physics program of the CMS experiment via data scouting and data parking.**

arXiv:2403.16134, Accepted in Physics Reports

**Searches for pair-produced multijet resonances using data scouting in proton-proton collisions at  $\sqrt{s} = 13$  TeV.**

arXiv:2404.02992, Published in PRL: 10.1103/PhysRevLett.133.201803

**Robust Anomaly Detection for Particle Physics Using Multi-Background and Nuisance-Aware Representation Learning.**

arXiv:2401.08777, Published in MLST: Mach.Learn.Sci.Tech. 5 (2024) 3, 035082

**Efficient and Robust Jet Tagging at the LHC with Knowledge Distillation.**

arXiv:2311.14160, Accepted at the ML and the Physical Sciences Workshop, NeurIPS 2023

**Fast Particle-based Anomaly Detection Algorithm with Variational Autoencoder.**

arXiv:2311.17162, Accepted at the ML and the Physical Sciences Workshop, NeurIPS 2023

**Anomaly Detection in the CMS Global Trigger Test Crate for Run 3.**

CERN-CMS-DP-2023-079

**Model selection and signal extraction using Gaussian Process regression.**

arXiv:2202.05856, Accepted in JHEP

**Physics Community Needs, Tools, and Resources for Machine Learning.**

arXiv:2203.16255, Contribution to Snowmass 2021

**Search for long-lived particles decaying into muon pairs in proton-proton collisions at  $\sqrt{s} = 13$  TeV collected with a dedicated high-rate data stream.**

arXiv:2112.13769, DOI: 10.1007/JHEP04(2022)062

**Searching for exotic B meson decays with the CMS L1 track trigger.**

arXiv:2008.06918, DOI: 10.1103/PhysRevD.103.015026

**Search for pair-produced three-jet resonances in proton-proton collisions at  $\sqrt{s} = 13$  TeV.**

arXiv:1810.10092, DOI: 10.1103/PhysRevD.99.012010

**First Level Track Jet Trigger for Displaced Jets at High Luminosity LHC.**

CMS PAS FTR-18-018, DOI: 10.23731/CYRM-2019-007.221, CERN CDS:2647987

**Higgs Physics at the HL-LHC and HE-LHC.**

CERN-LPCC-2018-04, arXiv:1902.00134

## The Phase-2 upgrade of the CMS Level-1 trigger.

CMS-TDR-021

### Other Service work

- Reviewer for Machine Learning and the Physical Sciences, at NeurIPS 2023 and 2024
- Organizer for the inaugural ML@L1 workshop, 2022 at Fermilab
- Co-chair for the LHC Physics Center Events committee, organizer LPC Physics forum
- Organizer for FNAL lab-wide AI meetings and LPC Physics Forum
- Served as mentor for the SURF, REU and RISE programs

### Talks

#### Colloquium

- 2025 **Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration**,  
Notre Dame University, South Bend
- 2025 **Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration**,  
Texas A&M, College Station

#### Seminars

- 2025 **Wine and Cheese Seminar, Fermilab, Batavia**,  
Beyond the Expected: Accelerating Discovery at the LHC
- 2024 **HEP Division Seminar, Argonne National Laboratory, Lemont**,  
Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration
- 2024 **HEE Seminar, University of Pennsylvania, Philadelphia**,  
Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration
- 2024 **Dark Cosmos seminar, Princeton University, Princeton** ,  
Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration
- 2024 **NPAC Seminar, University of Wisconsin, Madison**,  
Expanding Horizons: Novel Strategies in low mass BSM Physics Exploration
- 2023 **HEE Seminar, Boston University, Boston**,  
Breaking Boundaries: Novel Strategies in low mass BSM Physics Exploration with CMS
- 2020 **CHEP seminar, Indian Institute of Sciences, Bangalore**,  
Searching for low mass/HT resonances at the LHC using unconventional approaches
- 2020 **Physics Department seminar, IISER Pune**,  
Searching for low mass/HT resonances at the LHC using unconventional approaches

#### Conferences

- 2024 **"Realtime Anomaly Detection at the L1 Trigger of CMS"**, ICHEP 2024 , Prague, Czech Republic
- 2024 **"Lab AI&ML overview"**, Fermilab Users meeting 2024 , Batavia, IL
- 2024 **"Fast and Robust ML for uncovering BSM physics"**, ACAT 2024 , Stony Brook, NY
- 2023 **"Robust Anomaly Detection with NuRD"**, Boost 2023 , Berkeley, CA
- 2023 **"Search for New Resonances at CMS and ATLAS"**, Moriond QCD 2023, La Thuile, Italy
- 2022 **"Hunting for signals using Gaussian Process Regression"**, ML4Jets 2022, Piscataway, NJ
- 2022 **"Faster and Robust anomaly detection with NuRD"**, ML4Jets 2022, Piscataway, NJ

- 2022 **"Faster and Robust anomaly detection with NuRD"**, FastML 2022, Dallas, TX
- 2020 **"Search for low mass resonances using CMS data scouting"**, APS 2020, Washington, DC
- 2019 **"New Tools to hunt for Multi-jet resonances"**, QCD@LHC, University at Buffalo
- 2019 **"Trijets, RPV SUSY and Scouting"**, Plenary session talk at US CMS meeting, CUA
- 2019 **"Displaced Hybrid Tracking"**, Level 1 tracking workshop, Cornell university
- 2018 **"Exotic searches in multijet final states"**, Boosted Objects for New Physics Searches, Fermilab

Schools

- 2023 Lecturer for **"Machine Learning in HEP"**, CoDaS-HEP 2023, Princeton, NJ
- 2020 **Exploring Building Blocks of the Universe**, Regional Science Centre, Tirupati

Public talk

**Teaching, Mentoring, and Outreach Experience**

Graduate students mentored

- 2023-present **Chang Sun (Caltech)** *L1 Anomaly Detection and Fast ML*
- 2024-present **Aaron Wang (UIC)** *Efficient Transformers*
- 2023-present **Connor Hughton (Rutgers)** *Data scouting, di-tau resonances*
- 2023-present **John Steven Lawless (University of Tennessee)** *Generalized Multijet searches*

Undergraduates mentored

- 2023-present **Ryan Liu (UC Berkley)** *Efficient ML, Knowledge Distillation, Anomaly Detection*
- 2018-2020 **William Bidle (Rutgers)** *Quark Gluon tagging in PF Scouting using deep sets framework*
- 2018-2021 **Sindhu Murthy (Rutgers)** *Localised signals in smooth backgrounds using ML and Gaussian process regression*
- 2017-2021 **Beatrice Lingman (Rutgers)** *Search for low mass three-jet resonances with calo scouting, MC simulation*
- 2017-2018 **Steven Chen (Rutgers)** *Background signal fitting, Identifying localised signals using Gaussian processes*
- 2017-2018 **Duncan Adams (Rutgers)** *MC simulation, Effects of PDFs, boosted object re-clustering*

REU students mentored

- Summer 2017 **Hannah Glaser (REU)** *Boosted threejet resonances*
- Summer 2018 **Owen Tower (REU)** *Quark-Gluon Jet discrimination*
- Summer 2019 **Emily Mitchell (RISE)** *Anomaly detection using Autoencoders*

Outreach

- Summer 2017 **QuarkNet Instructor** *Rutgers University*
- Winter 2019 **Public talk aimed at school students** *Regional Science Centre, Tirupati, India*

Teaching assistant

- Spring 2019 General relativity
- 2016-2017 Advanced general physics
- Spring 2016 Analytical Physics II
- Fall 2015 Analytical Physics I