CURRICULUM VITAE

Marc Antoine Osherson

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CURRENT POSITION

Post-Doctoral Researcher, Rutgers University *2016 - present*
Member of the Compact Muon Solenoid collaboration (CMS) at the Large Hadron Collider (LHC).

EDUCATION

Ph.D. Physics, Johns Hopkins University *August 2016*
Thesis: *Z' Searches with New Heavy Fermions*, **Adviser:** Petar Maksimoviç
My thesis focused on background estimation methods for analyses where irreducible backgrounds cannot be simulated and must be obtained from data.

B.A. Physics, Princeton University *June 2010*
Thesis: *Cryogenic Refrigerators for Dark Matter Searches*, **Adviser:** Frank Calaprice
My research focused on the development of cheap and compact cryogenic refrigerators for liquid noble gas dark matter detectors.

LEADERSHIP AT CMS

Exotica: Jets+X Subgroup Co-Convener *2019 - present*
The Exotica group plans, reviews and publishes CMS results on exotic new physics signatures. As co-convener for the Jets+X subgroup my responsibility is to oversee analyses where the final states are dominated by hadornic (jet) activity. The subgroup has over a dozen active analyses.

JetMET: Algorithms and Reconstruction Subgroup Co-Convener *2018 - 2019*
The Jets and Missing Transverse Energy (JetMET) group is responsible for maintaining jet algorithms, reconstructing missing energy and applying energy scale corrections to hadronic activity at CMS. As subgroup co-convener I was responsible for the development and calibration of tools used to identify jets, reject pileup and tag heavy resonances, as well as for reviewing public results and publications on these topics.

CMS Certified Language Editor *2017 - present*
As a Publication Committee certified language editor I am responsible for ensuring the quality of publications and public results across the CMS collaboration.

Beyond 2 Generations: b-tagging Object Expert *2016 - 2019*
The Beyond 2 Generations (B2G) group reviews and publishes CMS results with final states including third generation quarks or gauge bosons. I was responsible for reviewing the use of b-tagging algorithms in these publications.

ONGOING RESEARCH ACTIVITIES

Searches for an Extended Higgs Sector using Collimated Photon Pairs: The recent gains in, and the accessibility of, image recognition artificial intelligence can be applied to any classification task which can be recast as an image recognition problem. One candidate is the readout of the CMS electromagnetic calorimeter: an arrays of detectors whose output can be translated into a pixelated image. These detectors are currently used to reconstruct photons and electrons based on measuring geometric relationships between crystal energy depositions. Considerable improvements over these

traditional techniques are possible with AI software. I am working on implementing these solutions to identify photons and detect exotic signals which may decay to multiple, overlapping particles; the latter is a signature which the current tools cannot identify, but which could be produced in certain models. In particular, a resonance decaying to pairs of di-photons, if the two photons are sufficiencly merged, would have escaped previous CMS searches despite relatively high production rates.

- Analysis under internal review: "Search for an extended Higgs sector using boosted di-photons"

Searches for Very Light Resonances decaying to Jets: As the energy of collider experiments increases, new physics models with low-mass signatures become increasingly difficult to detect. While the LHC is delivering higher energy collisions than ever before, this has resulted in a loss of sensitivity to lighter signals. In particular, low mass dark matter mediators may be produced alongside large background noise which is experimentally difficult to suppress. My latest analysis was nonetheless able to set limits on the production of such mediators by exploiting nonlinear correlations between variables to discriminate the signal from the background.

- Recently published in Physical Review Letters: "Search for low-mass quark-antiquark resonances produced in association with a photon at $\sqrt{s} = 13$ TeV"

Multijet Resonance Searches: Many interesting new physics models suggest new particles which do not decay directly to standard model objects, but decay in a cascade through other new particles. Even a seemingly simple decay: X→YY→qqqq makes for a complicated search: a mass scan needs to be performed in two dimensions and care must be taken to correctly combine the quarks. I am developing techniques and new observable perform coherent mass scans in two dimensions which can be sensitive to such new physics signals over a broad range of X and Y masses.

- Publication under internal review: "Search for resonant and non-resonant paired jet production at $\sqrt{s} = 13$ TeV"

Extending Search Ranges using Jet Scouting Data-sets: The CMS Detector fully reconstructs collision events at 1 kHz, orders of magnitude slower than the actual collision rate of the LHC. These events are excellent for precision physics, but the slow rate reduces our sensitivity to some signals. Recently we have begun to implement data-scouting: writing out events without fully reconstructing them. While the quality of this data is diminished, there are cases where this information is sufficient for meaningful physics analysis which might otherwise not be possible. I am adapting the algorithms used in fully reconstructed events to the scouting analyses.

- Analysis under internal review: "Search for pairs of boosted two and three-pronged jets in scouting data at $\sqrt{s} = 13$ TeV"

Searches for Physics decaying to Boosted Double-B Jets The discovery of the Higgs boson at the LHC finalizes the experimental verification of the Standard Model of Particle Physics, but many questions remain unanswered. Since 2015 I have been involved in analyses seeking to reconstruct exotic physics produced in collisions at the LHC which decay to two Higgs bosons. Such a signal could come from the decay of heavy particles to two Higgs bosons, or from anomalous two-Higgs couplings. These searches lean heavily on machine learning to identify individual Higgs bosons decaying pairs of b-quarks. Such jets can be identified from their two displaced vertices and substructure (bb-jets). Recently, I have extended these searches to new physics models in which additional scalars are present in the Higgs sector, in which a cascade decay of two new particles X→aa produces two such bb-jets.

- Publication under internal review: "Search for pairs of scalars produced from resonances in an extended Higgs sector at $\sqrt{s} = 13$ TeV"

CMS Detector: Outer Tracker for the HL-LHC: I am prototyping silicon particle detectors which will be added to the CMS Experiment before operation is switched to a high intensity mode. This

development involves the design and production of custom ASIC chip. I am responsible for developing the code used for the readout of these chips, and have organized both quality control procedures for the chip production, and testing of early modules at the Fermilab Test Beam Facility.

- Publication under internal review: "Test results of the Short Strip ASIC prototype module"

SELECT CONFERENCE AND WORKSHOP PRESENTATIONS

New results from searches with uncommon jet substructure. Plenary given at BOOST2019: 11th International Workshop on Boosted Object Phenomenology, Reconstruction and Searches in HEP, 21-26 Jul 2019, Cambridge, MA (United States).

Substructure for HH signatures. Plenary given at hh-2018: Double Higgs Production at Colliders, 4-8 Sep 2018, Batavia, IL (United States).

Novel substructure techniques and searches for new physics utilizing these techniques. Plenary given at 2018 US CMS Annual Collaboration Meeting, 16-19 May 2018, Minneapolis, MN (United States).

Recent CMS results on exotic searches. Plenary given at LIO: International conference on composite models, electroweak physics and the LHC, 5-8 Sep 2016, Lyon (France).

MENTORING

I have acted, in a research context, as a mentor or supervisor to the following students.

Graduate Students

- **Abhijith Gandrakota** (Rutgers University): I work closely with Abhijith on scouting analyses, especially on building tools to bring jet substructure, jet energy correction and jet mass groomers to the scouting dataset.
- **Steven Clark** (Rutgers University): I work closely with Steven on machine learning algorithms used to reconstruct closely collimated photons leaving merging clusters in the ECAL.
- **Alejandro Gomez Espinosa** (Rutgers University, now at ETH Zurich): I worked with Alejandro on searches for pair produced dijets in both the merged and resolved regime.
- **Michael Krohn** (UC Boulder, now at the University of Minnesota): I worked with Michael boosted Higgs searches, including a new search for semi-resolved decays of heavy resonances, which targeted masses around 750 GeV.

Undergraduate Students

- **Rikab Gambhir** (Rutgers University, now at MIT): I worked with Rikab on searches for pair produced vector-like quarks decaying to b-quarks and Higgs bosons in the 6 b-jet final state.
- **Chong Xia** (Rutgers Univesity, now at the University of Washington): I supervised several projects to categorize the behavior of ASIC chips which will be used in the new outer tracker for the HL-LHC.
- **Rebecca Kowalski** (Rutgers University, now at Johns Hopkins): I continue to work with Rebecca on a new analysis searching for boosted scalars produced by a heavy resonance and decaying to pairs of b-quarks.
- **Tai Wai Hu** (Rutgers University): Tai Wai and I work together on multi-jet SUSY searches.

- **Rakshay Kanthadai** (Rutgers University): Rakshay and I are working on using a specialized photon trigger implemented in the 2018 CMS data-set to isolate boosted very light vectors decaying to jets.

Other Students

- **Jean Somalwar** (then an exceptionally talented high school student, now a graduate student at California Institute of Technology): I supervised Jean's project on improving the sensitivity to boosted stop-stop production by categorizing events based on b-tag multiplicity.

TEACHING EXPERIENCE

I have taught, in the capacity of graduate teaching assistant, the following courses, all at Johns Hopkins:

- **Mechanics:** Course intended for engineering students as part of their pre-requisites.
- **Electricity and Magnetism:** Course intended for engineering students as part of their prerequisites.
- **Honors Electricity and Magnetism:** Course intended for physics majors, covering basic electricity and magnetism.
- **Physics Lab I & II:** Laboratory based course required for physics majors and engineers in their freshman year. I was the head lab TA for this course, supervising the entire class and responsible for setup of labs and grading rubrics.

VOLUNTEERING

America Needs You (NJ) *2019 - present*
America Needs You fights for economic mobility for ambitious, first-generation college students by providing mentor-ship and intensive career development. I am currently a mentor in the 2019 New Jersey cohort.

LANGUAGES

- English (Native)
- French (Native)
- Italian (Fluent)
- Spanish (Conversational)

PROFESSIONAL REFERENCES

- Eva Halkiadakis (Rutgers University)
- Scott Thomas (Rutgers University)
- Greg Landsberg (Brown University)
- Daniel Marlow (Princeton University)
- Anadi Capena (Fermilab National Accelerator Laboratory)
- Niki Saoulidou (National and Kapodistrian University of Athens)

PUBLICATIONS

Members of the CMS collaboration are authors on all papers published by the collaboration during their memberships. The full list of papers I am an author on can be found here, but a more relevant list appears in this section.

Publications on which I was the lead author or to which I made major contributions:

1. *Accepted by Phys. Rev. D. (2020)* "A search for bottom-type, vector-like quark pair production in a fully hadronic final state in proton-proton collisions at $\sqrt{s} = 13$ TeV"
2. Phys. Rev. Lett. 123, 231803 (2019): "Search for Low-Mass Quark-Antiquark Resonances Produced in Association with a Photon at $\sqrt{s} = 13$ TeV"
3. Phys. Rev. D 99, 012010 (2019): "Search for pair-produced three-jet resonances in proton-proton collisions at $\sqrt{s}$ =13 TeV"
4. J. High Energ. Phys. 2019, 40 (2019): "Search for production of Higgs boson pairs in the four b quark final state using large-area jets in proton-proton collisions at $\sqrt{s} = 13$ TeV"
5. Whitepaper, Di-Higgs at Colliders Workshop (2018): "Higgs boson potential at colliders: status and perspectives"
6. Phys. Rev. D 98, 112014 (2018): "Search for pair-produced resonances decaying to quark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV"
7. Phys. Lett. B 781, 244 (2018): "Search for a massive resonance decaying to a pair of Higgs bosons in the four b quark final state in proton–proton collisions at $\sqrt{s} = 13$ TeV"
8. Eur. Phys. J. C 77, 636 (2017): "Search for heavy resonances that decay into a vector boson and a Higgs boson in hadronic final states at $\sqrt{s}$ =13 TeV"
9. J. High Energ. Phys. 12, 17 (2014): "Identification techniques for highly boosted W bosons that decay into hadrons"

Publications to which I made substantive contributions as an editor or as a reviewer:

10. J. Inst 15, P06005 (2020): "Identification of heavy, energetic, hadronically decaying particles using machine-learning techniques"
11. J Inst 15, P09018 (2020): "Pileup mitigation at CMS in 13 TeV data"
12. J. High Energ. Phys. 01, 036 (2020): "Search for electroweak production of a vector-like T quark using fully hadronic final states"
13. Phys. Rev. Lett. 123, 241801 (2019): "Search for physics beyond the standard model in events with overlapping photons and jets"
14. Phys. Rev. D 97, 072006 (2018): "Search for massive resonances decaying into WW, WZ, ZZ, qW, and qZ with dijet final states at $\sqrt{s} = 13$ TeV"

Select publications which I was involved in, but for which I was not a major contributor:

15. Phys. Rev. D 100, 112007 (2019): "Search for low mass vector resonances decaying into quark-antiquark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV"
16. Phys. Rev. Lett. 122, 121803 (2019): "Combination of searches for Higgs boson pair production in proton-proton collisions at $\sqrt{s} = 13$ TeV"
17. Phys. Rev. D 99, 012005 (2019): "Search for low-mass resonances decaying into bottom quark-antiquark pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV"

18. J. High Energ. Phys. 03, 127 (2019): "Search for a W' boson decaying to a vector-like quark and a top or bottom quark in the all-jets final state"
19. Phys. Rev. Lett. 120, 071802 (2018): "Inclusive search for a highly boosted Higgs boson decaying to a bottom quark-antiquark pair"
20. J. High Energ. Phys. 08, 029 (2017): "Searches for W' bosons decaying to a top quark and a bottom quark in proton-proton collisions at 13 TeV"

Last updated: November 5, 2020