

# Matteo Cremonesi

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## PROFESSIONAL HISTORY

<b>Carnegie Mellon University</b> <i>Assistant Professor</i>	Pittsburgh, PA, US <i>Nov 2022 – Present</i>
<b>University of Notre Dame</b> <i>LHC Physics Center (LPC) Artificial Intelligence (AI) Fellow &amp; Research Associate</i>	Notre Dame, IN, US <i>Jul 2021 – Oct 2022</i>
<b>Fermi National Accelerator Laboratory (FNAL)</b> <i>Research Associate</i>	Batavia, IL, US <i>Jan 2015 – Jun 2021</i>

## EDUCATION

<b>University of Oxford</b> <i>PhD in Physics</i> <ul style="list-style-type: none"><li>Thesis title: <i>Observation of s-Channel Single Top Quark Production at the Tevatron</i></li><li>Advisors: Prof. Young-Kee Kim, Prof. Daniela Bortoletto, Dr. Chris Hays</li><li>Affiliated with the University of Chicago, IL, US, and with Harvard University, MA, US.</li><li>Degree obtained in two years due to outstanding achievements.</li></ul>	Oxford, UK <i>Oct 2012 – Jan 2015</i>
<b>University of Rome II</b> <i>MSc in Physics</i> <ul style="list-style-type: none"><li>Thesis title: <i>Development of a Multivariate Tool to Reject Background in a WZ Diboson Search for the CDF Experiment</i></li><li>Advisors: Prof. Giorgio Bellettini, Prof. Anna Di Ciaccio, Dr. Marco Trovato</li><li>Affiliated with the INFN, Pisa.</li><li>Grade: 110/110</li><li>Degree obtained <i>summa cum laude</i></li></ul>	Rome, Italy <i>Dec 2009 – May 2012</i>
<b>University of Rome II</b> <i>BSc in Physics</i> <ul style="list-style-type: none"><li>Thesis title: <i>Research of Possible Sources of Systematic Error in the Determination of the Emittance of a Brilliant Electron Beam for the SPARC Project</i></li><li>Advisors: Prof. Alessandro Cianchi</li><li>Grade: 110/110</li><li>Degree obtained <i>summa cum laude</i></li></ul>	Rome, Italy <i>Sep 2006 – Dec 2009</i>

## LEADERSHIP

<b>AccelerateAI Founder &amp; Principal Investigator</b> <ul style="list-style-type: none"><li>Founded a start-up, spin-off at FNAL, for the commercialization of software that allows specialized chips (FPGAs) to run artificial intelligence models more than 100x faster and with low power consumption. Recruited team of 10+ people composed by UChicago Booth MBA candidates, scientists, and technology transfer experts from IARC at FNAL (<a href="https://iarc.fnal.gov">https://iarc.fnal.gov</a>).</li></ul>	<i>Jan 2021 – Present</i>
<b>Delegate to the LHC Dark Matter Working Group, CMS Experiment</b> <ul style="list-style-type: none"><li>Co-coordinated the cross-experiment effort that defines a set of shared guidelines and recommendations for the Large Hadron Collider (LHC) experiments on dark matter benchmark models, as well as on interpretation, presentation, and characterisation of dark matter results (<a href="https://lpc.web.cern.ch/content/lhc-dm-wg-dark-matter-searches-lhc">https://lpc.web.cern.ch/content/lhc-dm-wg-dark-matter-searches-lhc</a>).</li></ul>	<i>Sep 2021 – Present</i>
<b>MET Group Convener, CMS Experiment</b> <ul style="list-style-type: none"><li>Co-led the group of 20+ people that studies the reconstruction and the calibration of the missing transverse momentum (MET), a key kinematic property for a large number of precision measurements and searches for new phenomena.</li></ul>	<i>Sep 2020 – Sep 2022</i>
<b>COFFEA Project Manager</b> <ul style="list-style-type: none"><li>Formed and coordinated the Column Object Framework For Effective Analysis project (COFFEA), a group of 30+ people that developed software tools to facilitate the performance of columnar analysis in Numpy with high energy physics data (<a href="https://github.com/CoffeaTeam">https://github.com/CoffeaTeam</a>).</li></ul>	<i>Sep 2018 – Sep 2021</i>
<b>LHC Big Data Project Manager</b> <ul style="list-style-type: none"><li>Built and directed a group of 30+ people that pioneered the usage of big data technologies like Apache-Spark for high energy physics data analysis (<a href="https://cms-big-data.github.io">https://cms-big-data.github.io</a>). Partnered with Intel Corporation.</li></ul>	<i>Jan 2015 – Sep 2018</i>
<b>Production and Reprocessing Group Manager</b> <ul style="list-style-type: none"><li>Co-led the group of 20+ people handling the reprocessing and the production of PB of simulations and detector data, orchestrating 250k cores worldwide.</li></ul>	<i>Jan 2015 – May 2019</i>
<b>TopBSM Group Convener, CDF Experiment</b> <ul style="list-style-type: none"><li>Co-led the group of 20+ people performing measurements of top quark and Higgs boson properties, and searches for new phenomena. A number of 15+ papers were published in peer reviewed journals.</li></ul>	<i>Oct 2014 – Present</i>
<b>Combiner, CDF Experiment</b> <ul style="list-style-type: none"><li>Co-led the effort of a group of 10+ people to observe the s-channel single top quark production.</li></ul>	<i>May 2013 – May 2015</i>

## AWARDS

<b>2021 LPC AI Fellowship</b> <ul style="list-style-type: none"><li>Awarded to outstanding researchers to develop ML applications for the CMS experiment.</li></ul>	<i>2021</i>
<b>2020 CMS Award</b> <ul style="list-style-type: none"><li>Awarded to individuals that have made outstanding contributions to different components of the CMS experiment.</li></ul>	<i>2020</i>
<b>FNAL Reward &amp; Recognition Award</b> <ul style="list-style-type: none"><li>Awarded in recognition to the leadership shown in the frame of the COFFEA project and to the contributions to the FNAL CMS Department's program.</li></ul>	<i>2020</i>
<b>I-Corps National Science Foundation Grant</b> <ul style="list-style-type: none"><li>Awarded to business ventures selected to participate in the UChicago Polsky Center for Entrepreneurship and Innovation I-Corps program to perform customer discovery.</li></ul>	<i>2020</i>
<b>2018 Junior CMS LPC Distinguished Researcher Fellowship</b> <ul style="list-style-type: none"><li>Fellowship awarded annually to outstanding young scientist that provides an opportunity to develop an independent research program.</li></ul>	<i>2018</i>
<b>2017 Junior CMS LPC Distinguished Researcher Fellowship</b> <ul style="list-style-type: none"><li>Fellowship awarded annually to outstanding young scientist that provides an opportunity to develop an independent research program.</li></ul>	<i>2017</i>
<b>Angelo Della Riccia Foundation Prize</b> <ul style="list-style-type: none"><li>Prize awarded annually to outstanding students in particle physics.</li></ul>	<i>2013</i>
<b>INFN Summer Student Scholarship</b> <ul style="list-style-type: none"><li>Scholarship awarded by INFN to selected Italian students to spend two months to work on particle physics experiments at FNAL.</li></ul>	<i>2010</i>
<b>Italian Ministry of Education Merit Scholarship</b> <ul style="list-style-type: none"><li>Three-year scholarship awarded by the Italian Ministry of Education to support outstanding students towards their BSc.</li></ul>	<i>2006</i>

My research area is elementary particle physics. In recent years, I have been leading searches for dark matter as a member of the Compact Muon Solenoid (CMS) collaboration. My work resulted in several publications in peer reviewed journals and in multiple talks at international conferences. Previously I led the Collider Detector at Fermilab (CDF) effort that brought to the observation of the  $s$ -channel single top quark production, the last discovery from the Tevatron program.

### CMS Experiment

Jan 2015 – Present

**L1 Trigger:** Developed software, as part of the hls4ml (<https://fastmachinelearning.org/hls4ml/>) tool, to deploy graph neural networks (GNNs) on field-programmable gate arrays (FPGAs), to be used in the upgrade of the CMS Level-1 (L1) trigger. Converted a GNN, previously trained to reconstruct MET, into FPGA firmware, to improve the MET trigger decision.

**GPUs:** Led the cost-benefit analysis of strategies for using GPUs to accelerate the computation of ML and non-ML algorithms in the frame of offline computing. Evaluated the potential of utilizing GPUs as-a-service, accessing them from remote locations, against locally connected GPUs, like the ones available at high-performance computing (HPC) centers.

**AccelerateAI:** Studied the commercialization potential of a software inspired by the hls4ml tool. Created a business venture, called AccelerateAI. Participated in the UChicago Polsky Center for Entrepreneurship and Innovation I-Corps program (<https://polsky.uchicago.edu/programs-events/polsky-i-corps/>) and awarded \$2.5k. Participated in UChicago Polsky Center for Entrepreneurship and Innovation Compass Accelerator, a six-month accelerator program for deep tech start-ups.

**MET:** Convened the MET group in CMS. Expanded the engagement of US institution in MET, by initiating a US-based support that leverages the LPC network. Promoted the utilization of ML techniques for MET reconstruction, and of columnar analysis tools to optimize MET analysis workflows. Developed a GNN for MET reconstruction (<https://github.com/DeepMETv2>), that shows a 5-to-15% improvement in resolution with respect to existing methods. Algorithm derived with the PyTorch package and trained over GPU resources. Studies of MET performance, including of the GNN MET, in CMS Run 2 are planned to be submitted for publication in Fall 2021.

**COFFEA:** Formed and directed the Column Object Framework For Effective Analysis project (COFFEA, <https://github.com/CoffeaTeam/coffea>), an effort that developed software tools to facilitate the performance of columnar analysis in Numpy with high energy physics data. A first prototype of the COFFEA framework showed a reduced analysis turnaround time by two orders of magnitude, with respect to common computing tools available to the Collaboration. COFFEA has been adopted by 30+ users in CMS and more outside CMS. Results submitted for publication in EPJ Web of Conferences (arXiv:2008.12712).

**LPC-DM:** Created and led the LPC-DM analysis team (<https://lpc-dm.github.io/>). The team is based at the LPC and analyzes data collected by the CMS experiment to search for dark matter. It is currently focusing on searches involving dark matter particles produced in association with jets or resonances, and on searches involving the production of long-lived particles. All the activities are performed within the CMS Exotica Group. Provided leadership, software resources, and human expertise that resulted in the execution of multiple analyses.

**Mono-X:** Co-led the mono-top analysis at CMS, looking for the associate production of dark matter and a single top quark decaying hadronically. At high top quark transverse momentum, hadronic decays of the top quark can be reconstructed as a single jet of large cone radius. Jet substructure information has been used to tag the top quark decays for the first time in the context of dark matter searches. Paper published in JHEP (**06** (2018) 027).

Co-led the search for the associate production of dark matter and a Higgs boson decaying to  $b\bar{b}$  (mono-Hbb), performed by applying the same analysis strategy used for mono-top. Paper published in EPJC (**79** (2019) 280).

Led the search for the associate production of dark matter and a dark Higgs boson decaying to  $b\bar{b}$ . Such processes are predicted in the context of a simple theoretical scenario where the dark Higgs boson is the responsible for the symmetry breaking in the dark sector. Expected publication in Fall 2021.

**Big Data:** Led the LHC Big Data Project (<https://cms-big-data.github.io/>), a partnership between FNAL, CERN-Openlab, and Intel Corporation that pioneered the usage of big data technologies, like Apache-Spark, for high energy physics data analysis. Coordinated the effort and developed the first functioning version of a HEP analysis code that employs the new software. Results published in EPJ Web of Conferences (**214**, 06030 (2019)).

### ATLAS Experiment

Apr 2014 – Oct 2014

**Fast Tracker:** Developed software for the Data Formatter system of the ATLAS FastTracKer (FTK) project. Contributed to the testing of the Pulsar Iia prototype board and to the firmware for the Pulsar Iib version. Results published in JINST (**10** (2015) C04032).

### CDF Experiment

Dec 2012 – May 2015

**Single top:** Led the  $s$ -channel single top quark search in events with large missing transverse energy and jets at CDF. Looking for single top events with  $t \rightarrow Wb$  when the  $W$  decays leptonically, and either the electron or muon escape detection, or the tau is reconstructed as a jet. Extended the search to events with no leptons, that added 33% of acceptance to the events with one reconstructed lepton. Used neural networks to classify and select  $s$ -channel single top quark events, improving the signal selection efficiency by more than one order of magnitude. Measured the  $s$ -channel single top quark cross section with an uncertainty of 53% and a significance of around  $2\sigma$ . Results included in the final  $s$ -channel Tevatron combination and contributed to the first observation of the process. Paper published in PRL (**112**, 231805 (2014)).

**Combination:** Led the  $s$ -channel single top quark combination for the Tevatron Working Group. Developed a framework to combine CDF and D0 analyses. The combination led to the first observation of the process. Paper published in PRL (**112**, 231803 (2014)).

**$W' \rightarrow t\bar{b}$ :** Led the CDF search for heavy  $W'$  bosons decaying into a top and a bottom quark. Employed neural networks to classify and select  $W'$  events, improving the signal selection efficiency by more than one order of magnitude. Achieved the best limits to the production cross sections of  $W'$  bosons with a mass below  $\sim 600$  GeV. Paper published in PRL (**115**, 061801 (2015)).

**Higgs spin/parity:** Contributed to the first measurement of the spin/parity of the Higgs boson when it decays to fermions. Trained neural networks to classify potential graviton and pseudoscalar Higgs bosons in events where the Higgs is produced in association with a Z boson decaying into a neutrino pair, used as inputs to the final Tevatron combination. Set limits on both the graviton and pseudoscalar hypothesis for the Higgs boson. Paper published in PRL (**114**, 151802 (2015)).

### SELECTED PUBLICATIONS

List of publications to which I contributed as primary author:

*Coffea – Columnar Object Framework For Effective Analysis*; N. Smith *et al.*, EPJ Web of Conferences **245**, 06012 (2020).

- Had the original idea and designed the tool described in the paper. Created the effort, founded the team, and recruited the members that developed the tool. Co-led the project and managed the interaction with the user community.

*Using Big Data Technologies for HEP Analysis*; M. Cremonesi *et al.*, EPJ Web of Conferences **214**, 06030 (2019).

- Co-led the team that performed the investigation, designed the tests of the performances of the new analysis tools previously developed. Main editor and corresponding author of the paper.

*Search for dark matter produced in association with a Higgs boson decaying to a pair of bottom quarks in proton-proton collisions at  $\sqrt{s} = 13$  TeV*; A. M. Sirunyan *et al.* (CMS Collaboration), Eur. Phys. J. C **79** (2019) 280.

- Co-led the analysis, responsible for the analysis design (adoption of 1.5 cone jets, strategy for data-driven background model, and in-situ calibration of Higgs-tagger scale factors), studied the inputs to and implemented a special version of a Higgs-tagger for 1.5 cone jets, co-editor of the paper.

*Search for dark matter in events with energetic, hadronically decaying top quarks and missing transverse momentum at  $\sqrt{s} = 13$  TeV*; A. M. Sirunyan *et al.* (CMS Collaboration), JHEP **06**(2018)027.

- Co-led the analysis, responsible for the analysis design (adoption of 1.5 cone jets, strategy for data-driven background model), pioneered the usage of top-tagging, co-editor of the paper.

*CMS Analysis and Data Reduction with Apache Spark*; O. Gutsche *et al.*, JPCS **1085** 042030 (2018).

- Co-lead the team that performed the investigation, directed the development of new computing tools based on the usage of Apache Spark in a context of HEP analysis.

*Big Data in HEP: A comprehensive use case study*; O. Gutsche *et al.*, JPCS **898**, 072012 (2017).

- Founded and led the team that performed the investigation, established partnership with Intel Corp. through CERN Openlab to get fundings for a software engineer, strategized the application of big data technologies to a real analysis use-case. Co-editor of the paper.

*Observation of s-Channel Production of Single Top Quarks at the Tevatron*; T. Aaltonen *et al.* (CDF and D0 Collaborations), Phys. Rev. Lett. **112**, 231803 (2014).

- Performed the statistical combination of CDF and D0 results to achieve the first observation of the s-channel single top quark production. Selected as speaker for the announcement of the discovery. Co-editor and corresponding author of the paper.
- Selected as PRL Editors' Suggestion

*Search for s-Channel Single-Top-Quark Production in Events with Missing Energy Plus Jets in  $p\bar{p}$  Collisions at  $\sqrt{s} = 1.96$  TeV*; T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **112**, 231805 (2014).

- Led the search for s-channel single top quark production in events with missing transverse momentum and hadronic jets with CDF data. Responsible for all the aspects of the search, from the analysis design to the code development. Improved the model of the main V+jets background by properly accounting for the varying heavy-flavor fraction. Main editor and corresponding author of the paper.

*Tevatron Combination of Single-Top-Quark Cross Sections and Determination of the Magnitude of the Cabibbo-Kobayashi-Maskawa Matrix Element  $|V_{tb}|$* ; T. Aaltonen *et al.* (CDF and D0 Collaborations), Phys. Rev. Lett. **115**, 152003 (2015).

- Performed the statistical combination of the CDF measurements. Main editor and corresponding author of the paper.

*Search for Resonances Decaying to Top and Bottom Quarks with the CDF Experiment*; T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **115**, 061801 (2015).

- Optimized the search by importing the machinery used for the observation of the s-channel single top quark production and by the massive use of machine learning techniques. Corresponding author of the paper.

*Measurement of the single top quark production cross section and  $|V_{tb}|$  in 1.96 TeV  $p\bar{p}$  collisions with missing transverse energy and jets and final CDF combination*; T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. D **93**, 032011 (2016).

- Led the measurement of single top quark production cross section in events with missing transverse momentum and hadronic jets with CDF data. Main editor and corresponding author of the paper.

*Constraints on Models of the Higgs Boson with Exotic Spin and Parity using Decays to Bottom-Antibottom Quarks in the Full CDF Data Set*; T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **114**, 141802 (2015).

- Led the measurement of the Higgs boson spin-parity in events with missing transverse momentum and hadronic jets with CDF data, that served as input to the CDF combination. Improved the measurement by massively using machine learning techniques. Contributed to the final combination and to the paper editing.

*Tevatron Constraints on Models of the Higgs Boson with Exotic Spin and Parity Using Decays to Bottom-Antibottom Quark Pairs*; T. Aaltonen *et al.* (CDF Collaboration), Phys. Rev. Lett. **114**, 151802 (2015).

- Contributed to the final combination and to the paper editing.
- Selected as PRL Editors' Suggestion

## TALKS

### Invited

<b>Aspen Winter Particle Physics Conference</b> "LHC Dark Matter Searches", Plenary Talk	Aspen, CO, US Mar 2019
<b>DM2018</b> "Dark matter results from ATLAS and CMS", Plenary Talk	Los Angeles, CA, US Feb 2018
<b>Blois 2017</b> "Searches for Dark Matter and New Physics in ATLAS and CMS", Parallel Session	Blois, France May 2017
<b>DS@HEP Workshop 2017</b> "Infrastructure for Large Scale HEP data analysis", Plenary Talk	Batavia, IL, US May 2017
<b>NPI-ANL2017: New Physics Interpretations at the LHC</b> "Searching for Dark Matter at Colliders", Plenary Talk	Lemont, IL, US Apr 2017
<b>Moriond EWK 2016</b> "Generic search for Dark Matter at LHC 13TeV", Plenary Talk	LaThuile, Italy Mar 2016
<b>Moriond QCD 2015</b> "Recent Top Quark Properties Results from the Tevatron", Plenary Talk	LaThuile, Italy Mar 2015
<b>Moriond QCD 2014</b> "Single Top Production at the Tevatron", Plenary Talk	LaThuile, Italy Mar 2014
<b>Joint CDF+D0 Wine &amp; Cheese Seminar</b> "Observation of s-channel single top quark production at the Tevatron", Seminar	Batavia, IL, US Feb 2014
<b>TOP 2013</b> "Single top at the Tevatron", Plenary Talk	Durbach, Germany Sep 2013

### Other

<b>CHEP 2018</b> "Using Big Data Technologies for HEP Analysis", Parallel Session	Sofia, Bulgaria Jul 2018
<b>CHEP 2018</b> "Challenges of Processing Growing Volumes of Data for the CMS Experiment During the LHC Run2", Parallel Session	Sofia, Bulgaria Jul 2018
<b>DPF 2017</b> "CMS Software and Computing in LHC Run 2 (and Beyond)", Parallel Session	Batavia, IL, US Jul 2017
<b>DPF 2013</b> "Measurement of s-channel single-top-quark production in MET+jets at CDF", Parallel Session	Santa Cruz, CA, US Aug 2013
<b>Higgs Hunting 2013</b> "Single Top s-channel at CDF", Young Scientist Forum Talk	Orsay, France Jul 2013

Invited speaker for several seminars at prestigious institutions, like Harvard, Berkeley and MIT.

## CONFERENCE AND WORKSHOP ORGANIZATION

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<b>APS 2021 April Meeting</b> <i>Sorter and Session Chair</i>	Virtual Apr 2021
<b>Future of Collider Searches for Dark Matter</b> <i>Co-Chair of the Organizing Committee</i>	Batavia, IL, US Jul 2017
<b>TOP 2016</b> <i>Member of the International Advisory Committee</i>	Olomouch, Czech Republic Sep 2016
<b>TOP 2015</b> <i>Member of the International Advisory Committee</i>	Ischia, Italy Sep 2015
<b>Top@Twenty</b> <i>Member of the International Advisory Committee</i>	Batavia, IL, US Apr 2015

## MENTOR EXPERIENCE

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<b>Abhishek Das</b> <i>Supervisor</i>	PhD student, Notre Dame 2021–Present
<b>Jongho Lee</b> <i>Supervisor</i>	LPC Guest & Visitor 2019–2022
<b>Felipe Navarro</b> <i>Supervisor</i>	LPC Guest & Visitor 2018–2019
<b>Diana Leon Silverio</b> <i>Supervisor</i>	LPC Guest & Visitor 2017–2019
<b>Sonaina Undleeb</b> <i>Supervisor</i>	LPC Guest & Visitor 2017–2019
<b>Sunil Dogra</b> <i>Supervisor</i>	LPC Guest & Visitor 2017
<b>Siew-Yan Hoh</b> <i>Supervisor</i>	LPC Guest & Visitor 2017
<b>Jorge Martinez</b> <i>Supervisor</i>	LPC Guest & Visitor 2017
<b>Allison Reinsvold</b> <i>Supervisor</i>	PhD student, Notre Dame 2016
<b>Sid Narayanan</b> <i>Supervisor</i>	PhD student, MIT 2015
<b>Ruturaj Apte</b> <i>Supervisor</i>	PhD student, Rutgers 2016
<b>Cristina Mantilla Suarez</b> <i>Supervisor</i>	LPC Guest & Visitor 2015–2016
<b>Ludovico Bianchi</b> <i>Co-Advisor</i>	MSc student, Rome II 2012–2013
<ul style="list-style-type: none"><li>• Thesis title: <i>Search for <math>W' \rightarrow tb</math> in Events with Large Missing Transverse Energy and Jets with the CDF detector at the Fermilab Tevatron Collider</i></li><li>• Grade: 110/110</li><li>• Degree obtained <i>summa cum laude</i></li></ul>	

## MEDIA COVERAGE

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The observation of the  $s$ -channel single top quark production spurred press release from Fermilab which was carried over a number of internet outlets and scientific blogs. It was followed by several articles:

*CERN Courier*; Apr. 2014 issue (Vol. 54, No. 3).

- <http://cerncourier.com/cws/article/cern/56587>

*Fermilab Today*; Feb. 24, 2014.

- [http://www.fnal.gov/pub/today/archive/archive\\_2014/today14-02-24.html](http://www.fnal.gov/pub/today/archive/archive_2014/today14-02-24.html)

*Physics*; June 9, 2014 (Vol. 7, 61).

- <http://physics.aps.org/articles/v7/61>

## OTHER

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<b>Intro to Venture Capital: A Toolkit for Analyzing and Financing Startups</b> • Attended the "Intro to Venture Capital: A Toolkit for Analyzing and Financing Startups" class at the The University of Chicago Booth School of Business.	2020
<b>Entrepreneurship and Commercialization Practicum</b> • Graduated from the "Entrepreneurship and Commercialization Practicum" hosted at FNAL.	2019