Marco Del Tutto

Research Positions

2019 - present **Lederman Fellow**, *Fermi National Accelerator Laboratory*
Postdoctoral fellow working on the SBND and MicroBooNE experiments.

2019 **Postdoctoral Fellow**, *Harvard University*
Postdoctoral fellow working on the MicroBooNE and NEXT experiments.

Education

2015 – 2019 **PhD in Particle Physics**, *University of Oxford, UK*
Title of the thesis: First Measurements of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon at 0.8 GeV Average Neutrino Energy with the MicroBooNE Detector. Phys. Rev. Lett. 123, 131801
Advisors: Prof. Roxanne Guenette, Prof. Giles Barr

2013 – 2015 **Master's Degree in Physics cum laude**, *University of Rome "Sapienza"*
Title of the thesis: Neutrino Beam Simulations and Data Checks for the NOνA Experiment. The thesis work has been done at the Fermi National Accelerator Laboratory (Fermilab, Batavia, IL, USA) from March to September 2015.

2010 – 2013 **Bachelor's Degree in Physics cum laude**, *University of Rome "Sapienza"*
Title of the thesis: Onde gravitazionali da sistemi binari di pulsar (Gravitational waves form binary pulsars systems).

Roles and Responsibilities

2022-present **ArCS Principal Investigator**
PI of the LDRD-awarded ArCS (Argon detector with Charge Separation) experiment at Fermilab that will run a magnetized LArTPC on the Fermilab test beam.

2021-present **SBND Simulation Convener**
Convener of the simulation groups and responsible for the simulation software. Main contributor of SBND offline software: github.com/SBNSoftware/sbndcode/graphs/contributors.

2021-present **SBN Simulation Infrastructure Convener**
Convener of the simulation infrastructure group inside the Short Baseline Neutrino program and responsible for shared SBND-ICARUS simulation software.

2020-2022 **SBND Commissioning Deputy Coordinator**
Deputy commissioning coordinator of SBND, responsible for the activities in preparation to commissioning the detector.

Research Projects

2020-present **SBND-PRISM**
Proponent of SBND-PRISM, a concept that allows sampling multiple neutrino fluxes using the same SBND detector. I pioneered SBND-PRISM data analyses exploiting this concept for several physics cases.

2020-present **Magnetized LArTPC**
Led the feasibility study of adding a magnetic field to a liquid argon time projection chamber detector for neutrino physics. I was awarded an LDRD grant and am now building a prototype detector.

Fermi National Accelerator Lab – Batavia, IL, USA
+1 630 210 1653 • *mdeltutt@fnal.gov* • *marcodeltutto.com*

2020-present **SBND Purity Monitors**

Led the design and construction of the SBND purity monitor system, which will allow monitoring the electron lifetime in the argon, critical for calorimetric measurements in SBND.

2021-present **Machine Learning for Vertex Reconstruction in LArTPCs**

Awarded computing time on Argonne National Lab's supercomputers to develop algorithms to identify particle's vertices in liquid argon time projection chambers using convolutional neural networks.

2021-present **Dark Neutrino Data Analysis with SBND Cosmic Ray Tagger System**

Analysis leader a dark neutrino search using data from the SBND cosmic ray tagger system. I am supervising two students working on the analysis and I am collaborating with the Fermilab Theory group in developing analysis strategies, signal sensitivities, and signal sample generation.

2020-2021 **Cosmogenic Background Determination in SBND**

Led the analysis of different cosmogenic background contributions in SBND and the effect of the materials surrounding the detectors to these cosmogenic particles. This analysis had the impact of changing the original experiment design, saving $300k.

2019-2020 **Pixel-Based 3D Readout for LArTPCs with Machine Learning**

Explored the potential improvements in neutrino event reconstruction that a 3D pixelated readout could offer over a 2D projective wire readout for liquid argon time projection chambers. The study was done using deep convolutional neural networks. JINST **15** P04009

2019 **Signal/Background Identification in the NEXT Experiment with Machine Learning**

Led the analysis of event classification with convolutional neural networks in the NEXT experiment, which will search for neutrinoless double-beta decay in ^{136}Xe. J. High Energ. Phys. **2021** 189

2015-2019 **Muon-Neutrino Cross-Section Measurement with Argon**

Performed the first MicroBooNE analysis that produced a double differential cross-section measurement on argon. Developed the full analysis framework, from the cross-section extraction to the software that evaluates the systematic uncertainties, Phys.Rev.Lett. **123** 131801.

2015-2019 **Neutrino Event Selection Tools**

Developed several tools to identify neutrino interactions in MicroBooNE, among which the track-to-flash matching, which combines particle track information from the TPC with the optical data from the photomultiplier system.

2015-2019 **Cosmogenic Background Identification Techniques**

Developed several algorithms to identify cosmogenic background events in the MicroBooNE detector. With MicroBooNE being located on the Earth's surface, cosmic rays are a primary background for many physics analyses.

2014-2015 **Accelerator Neutrino Flux Simulation**

Led simulations of the neutrino beam flux from accelerators and studies beamline optimizations to improve the neutrino intensity.

Teaching Experience

2019-present **Supervisor of Students**

Currently supervising more than 10 students and junior postdocs working on the SBND experiment of a variety of different projects: SBND-PRISM, cosmic-ray-tagger data analysis, cosmogenic studies, neutrino fluxes, SBND commissioning, and more.

2019 **Supervisor of Student for Italian Summer Student Program**

Supervised student from the Italian Summer Student Program during the summer of 2019 on SBND-PRISM data analyses.

2018 **Teacher at the First Oxford Virtual and Augmented Reality Summer School**

Teacher at the first Oxford Virtual and Augmented Reality Summer School. Leader of a group of student in the making of their first Virtual Reality application.

2017 **High Energy Physics Lab. Demonstrator at the University of Oxford**
Demonstrator at the particle physics laboratory in Oxford.

2017 **Supervisor of Oxford Summer Students**
Supervised one student for the whole summer both in Oxford and at Fermilab.

Awards

2022 **Fermilab Lab-Directed R&D (LDRD)**
Awarded a Fermilab LDRD of the value of $0.57M to run the ArCS (Argon detector with Charge Separation) experiment: a magnetized liquid-argon time-projection chamber detector on the Fermilab test beam (see ldrd.fnal.gov).

2021 **Rising Stars Symposium at the University of Chicago**
Selected to participate in the *Rising Stars in Experimental Particle Physics* symposium organized by the University of Chicago: a platform for exceptional early-career scientists in the broad field of physics to present their work (see physics.uchicago.edu/events/workshops/rising-stars-symposia/).

2021 **ADSP Award**
Awarded resources to advance the use of artificial intelligence in neutrino physics at the Argonne National Laboratory (see `https://tinyurl.com/2nhhcbf7`).

2020 **Exceptional Performance Recognition Award Program**
Awarded this Fermilab prize "for significant design and development contributions to the Mechanical Ventilator Milano." (See `https://mvm.care`).

2020 **Fermilab Reward and Recognition**
Awarded this Fermilab prize "for doing a fantastic job on the Neutrino 2020 conference." (See `https://nu2020.fnal.gov`).

2016 **Donald H. Perkins Prize**
Awarded this prize for outstanding performance in the first year of postgraduate study at the University of Oxford.

2016 1^{st} **Prize Particle Physics Art Competition**
Awarded this prize during the Particle Physics Art Competition at the University of Oxford.

2015 **ARAP Prize in Experimental Particle Physics**
The Roman Astro-Particle Association (ARAP) promotes a prize in experimental particle physics designed to reward Master's degree deserving students in particle physics.

2015 **Scholarship for Master's thesis project**
Awarded by Fermilab to conduct research work for the completion of my Master's Degree with the NOvA experiment.

2014 **Summer Student at Fermilab**
Awarded by the Italian Summer Student Program to conduct research at Fermilab on the NOvA experiment.

Scientific-Community Service

Journal Referee
JINST, Universe

Neutrino Physics and Machine Learning Workshop
Organizer of the NPML workshop on machine learning in neutrino physics, indico.slac.stanford.edu/event/371/.

Neutrino 2020
Organizer of the Neutrino 2020 conference, nu2020.fnal.gov.

Machine Learning Seminar Convener
Convener of the machine learning seminar series at the Department of Physics of Oxford University.

Conferences and Talks

2022 **NuFact 2022 Conference**, *Salt Lake City, Utah, U.S.A., August 2022*
Talk on *SBND-PRISM: Sampling Multiple Off-Axes Fluxes with the Same Detector*
Slides: https://indico.fnal.gov/event/53004/contributions/244480/

2022 **Snowmass Meeting**, *Seattle, WA, U.S.A., July 2022*
Invited Talk on *VENu: Virtual Reality App*
Slides: https://indico.fnal.gov/event/22303/contributions/244951/

2022 **ICHEP 2022 Conference**, *Bologna, Italy, 8 July 2022*
Talk on *SBND-PRISM: Sampling Multiple Off-Axes Fluxes with the Same Detector*
Slides: https://agenda.infn.it/event/28874/contributions/170211/

2022 **Fermilab Users Meeting**, *Fermilab, 16 June 2022*
Invited Talk on *SBND: Short-Baseline Near Detector*
Slides: https://indico.fnal.gov/event/53944/contributions/242504/

2021 **Rising Stars in Experimental Particle Physics**, *University of Chicago, Virtual, 22 Sept 2021*
Invited Talk on *SBND-PRISM: Sampling Multiple Off-Axes Neutrino Fluxes with the Same Detector*
Abstract: https://indico.uchicago.edu/event/107/contributions/79/

2021 **APS April Meeting 2021**, *Virtual, 20 Apr 2021*
Talk on *SBND-PRISM: Sampling Multiple Off-Axes Fluxes with the Same Detector*
Abstract: https://meetings.aps.org/Meeting/APR21/Session/Z12.5

2021 **Joint Experimental-Theoretical Physics Seminar (Wine and Cheese Seminar)**, *Virtual, 12 Feb 2021*
Invited Talk on *The Mechanical Ventilator Milano: A Novel Ventilator for the COVID-19 Pandemic*
Slides and Recording: https://theory.fnal.gov/events/event/tbd-101/

2020 **Neutrino Physics and Machine Learning Workshop**, *Virtual, 22 Jul 2020*
Talk on *Enhancing Neutrino Event Reconstruction with Pixel-Based 3D Readout for Liquid Argon Time Projection Chambers*
Slides and Recording: https://indico.slac.stanford.edu/event/371/timetable/

2019 **Neutrino Cross-Section Data Tensions Workshop**, *Pittsburgh, 8 Jul 2019*
Talk on *Muon-Neutrino Charged-Current Inclusive Cross-Section Measurement from MicroBooNE*

2019 **Joint Experimental-Theoretical Physics Seminar (Wine and Cheese Seminar)**, *Fermilab, 24 May 2019*
Invited Seminar on *First Muon-Neutrino Charged-Current Inclusive Cross-Section Measurement from MicroBooNE*
Slides and Recording: https://theory.fnal.gov/events/event/results-from-microboone-2/

2018 **Harvard University - Laboratory for Particle Physics and Cosmology Seminar**, *31 October 2018*
Invited Seminar on *First Muon Neutrino Charged-Current Inclusive Cross Section Measurement in MicroBooNE*

2018 **NuINT**, *GSSI - Italy, 16 October 2018*
Invited Talk on *First Muon Neutrino Charged-Current Inclusive Cross Section Measurement in MicroBooNE*
Slides: https://indico.cern.ch/event/703880/contributions/3159000/

2018 **GDR Neutrino Meeting**, *Paris - France, 11 June 2018*
Invited Talk on *VENu: The Virtual Environment for Neutrinos*
Slides: https://indico.in2p3.fr/event/17494/

2018 **Neutrino2018**, *Heidelberg - Germany, 6 June 2018*
Poster on *First Muon Neutrino Charged-Current Inclusive Cross Section Measurement in MicroBooNE*
Proceedings: https://doi.org/10.5281/zenodo.1300795

2018 **Nu-Print, Neutrino Cross Section Strategy Workshop**, *Fermilab - USA, 13 March 2018*
Invited Talk on *MicroBooNE Future Cross Section Measurements and Capabilities*
Slides: https://indico.fnal.gov/event/15849/session/3/contribution/13

2017 **NUFACT2017**, *Uppsala - Sweden, 26 September 2017*
Invited Talk on *Cross Section Prospects for MicroBooNE*
Proceedings: https://pos.sissa.it/295/068/

2017 **APS, Division of Particles and Fields Meeting**, *Fermilab - USA, 2 August 2017*
Talk on *VENu: The Virtual Environment for Neutrinos*
Proceedings: https://arxiv.org/abs/1709.10120

2017 **Rencontres de Moriond**, *La Thuile - Italy, 21 March 2017*
Invited Talk on *Neutrino Interactions at MicroBooNE*
Proceedings: https://arxiv.org/abs/1705.04894

2016 **Neutrino2016**, *London - UK, 5 July 2016*
Poster on *Model Uncertainties at MicroBooNE*
Proceedings: http://iopscience.iop.org/article/10.1088/1742-6596/888/1/012140

Outreach

VENu, *Virtual Environment for Neutrinos*
I am the main author of the *VENu* (Virtual Environment for Neutrinos). VENu is a mobile app to visualize data from the MicroBooNE experiment on smartphones. It also has a 3D Virtual Reality feature the immerse the users inside the detector. Link: http://venu.physics.ox.ac.uk. VENu was fearured in several media outlets:

- Podcast: IOP Physics World.
- Interview: International Business Times.
- Interview: Local TV "That's Oxfordshire".
- Interview: Fermilab.
- Interview: Oxford.

Collider
I worked on a mobile app to show events from the ATLAS detector at CERN, called *Collider*: http://collider.physics.ox.ac.uk.

2017 **Stargazing**, *Oxford University*
Launched the VENu app.

2017 **Chicago Science Festival**, *Chicago*
Showcase of the VENu app in a Fermilab stall.

2017 **Oxford Garden Party**, *Oxford University*
Neutrino physics explained via the VENu app to Oxford visitors.

Software

Here, I list the main softwares I have developed during my research where I had a crucial part in the development effort.

sbndcode	Main contributor of the SBND simulation off-line software.
PurityMonitorDAQ	Author the Phyton-based DAQ system for the SBND purity monitors.
VertexID	Main author of VertexID, a neural network for vertex identification in LArTPC detectors.
Python Tutorial	Wrote and gave Python tutorials to the SBN collaboration.
larcv3	Core developer of larcv3: a fast I/O software for machine learning training and inference, particularly designed for sparse data.
UBAna	Author of the software stack used for the firsts MicroBooNE cross-section measurements: UBAna.
VENu	Core developer of of VENu: a mobile app to visualize data from the MicroBooNE experiment on phones or tablets.
Collider	Core developer of Collider: a mobile app to visualize data from the ATLAS experiment on phones or tablets.
MVM	Core developer of Mechanical Ventilator Milano software, developed in response to the COVID-19 pandemic.
Websites	Developed substantial skills in website development. Some examples: microboone.fnal.gov, venu.physics.ox.ac.uk, collider.physics.ox.ac.uk.

Publications

I have an h-index of 27, from 52 published papers with over 2300 citations in total and an average of 46 citations per paper. A main highlight is the work for my PhD thesis, published in Physical Review Letters, and with more than 60 citations. Below is a list of selected publications, while my full set of publications can be found on Inspire: inspirehep.net/authors/1404347.

Most Impactful Publications

SBND, Cross Sections, and Medical Physics

My most impactful publications cover a variety of topics, from innovative machine-learning techniques to select events in TPC detectors, to an original visualisation tool for LArTPC data, to a full review of the current neutrino interaction measurements available, to a new ventilator to fight the COVID-19 pandemic published in a journal of medical physics.

2022 M. Buizza Avanzini, M. Del Tutto, et al, *Comparisons and challenges of modern neutrino-scattering experiments*, Phys. Rev. **D** 105, 092004

2021 NEXT Collaboration, M.D.T., *Demonstration of background rejection using deep convolutional neural networks in the NEXT experiment*, J. High Energ. Phys. **2021**, 189

2021 MVM Collaboration, M.D.T., *The novel Mechanical Ventilator Milano for the COVID-19 pandemic*, Physics of Fluids **33**, 037122

2020 C. Adams, M. Del Tutto, et al., *Enhancing neutrino event reconstruction with pixel-based 3D readout for liquid argon time projection chambers*, JINST **15** P04009

2020 C. Adams, M. Del Tutto, *TITUS: Visualization of Neutrino Events in Liquid Argon Time Projection Chambers*, Instruments **2020**, 4, 31

MicroBooNE

In MicroBooNE, I single-handedly performed the first precision physics measurement of the experiment: the first ever double-differential cross section measurement for neutrino interactions on argon. This analysis has been a major milestone of the experiment, and many subsequent analyses that MicroBooNE produced have either been based on my work or have used tools and techniques developed and pioneered by me. In particular, my work formed the basis of the electron-neutrino low energy excess search, MicroBooNE's latest result. During my PhD, I also contributed significantly to the assembly and testing of MicroBooNE's cosmic ray tagger. The following selected list of papers represents publications where I played a leading or major role.

2022 MicroBooNE Collaboration, *Search for an Excess of Electron Neutrino Interactions in MicroBooNE Using Multiple Final State Topologies*, Phys. Rev. Lett. **128**, 241801

2022 MicroBooNE Collaboration, *Search for an anomalous excess of charged-current ν_e interactions without pions in the final state with the MicroBooNE experiment*, Phys. Rev. D **105**, 112004

2022 MicroBooNE Collaboration, *First measurement of inclusive electron-neutrino and antineutrino charged current differential cross sections in charged lepton energy on argon in MicroBooNE*, Phys. Rev. **D** 105 5, L051102

2021 MicroBooNE Collaboration, *Measurement of the flux-averaged inclusive charged-current electron neutrino and antineutrino cross section on argon using the NuMI beam and the MicroBooNE detector*, Phys. Rev. D **104**, 052002

2020 MicroBooNE Collaboration, *Measurement of differential cross sections for ν_μ-Ar charged-current interactions with protons and no pions in the final state with the MicroBooNE detector*, Phys. Rev. D **102**, 112013

2019 MicroBooNE Collaboration, *First Measurement of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon at $E_\nu \sim 0.8$ GeV with the MicroBooNE Detector*, Phys. Rev. Lett. **123**, 131801

2017 M. Auger, M.D.T., et al., *A Novel Cosmic Ray Tagger System for Liquid Argon Neutrino Detectors*, Instruments **2017**, 1(1), 2

2017 MicroBooNE Collaboration, *Design and Construction of the MicroBooNE Detector*, JINST **12** P02017

NOvA

During my Master's, I joined the NOvA neutrino experiment to become an expert in neutrino beams and was appointed responsible for special data-taking runs to better understand the beam. I made sever crucial contributions to the neutrino beam simulation and modelling in the NOvA experiment.

2016 NOvA Collaboration, *First Measurement of Electron Neutrino Appearance in NOvA*, Phys. Rev. Lett. **116**, 151806

2016 NOvA Collaboration, *First measurement of muon-neutrino disappearance in NOvA*, Phys. Rev. D **93**, 051104(R)

Fermi National Accelerator Lab – Batavia, IL, USA
+1 630 210 1653 • *mdeltutt@fnal.gov* • *marcodeltutto.com*