DICHIARAZIONE SOSTITUTIVA DI ATTO DI NOTORIETA' E DI CERTIFICAZIONE

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Curriculum vitæ et studiorum Gianantonio Pezzullo

CONTACT INFORMATION

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WORKING EXPERIENCE

Since February 2022 – Associate Research Scientist at Yale University working on the Mu2e experiment at Fermilab and the ATLAS experiment at CERN.
February 2018 - February 2022 – Postdoctoral Research Associate at Yale University working on the Mu2e experiment at Fermilab and the ATLAS experiment at CERN.
April 2016 - February 2018 – Postdoctoral Research at the INFN of Pisa, working on the Mu2e experiment.

EDUCATION

March 2016 – Ph.D. in Physics at the University of Pisa.
Ocotber 2012 – Master's degree in Physics from the University of Pisa.
October 2010 – Bachelor's degree from the University of Pisa.

LANGUAGES

Italian – Native language.
English – Excelent in writing, reading and conversation.
French – Good in writing, reading and conversation.

COMPUTER SKILLS

Operating systems – Windows, Mac OSX, Unix/Linux.
Programming languages – C/C++, Condor, Python, bash, HTML.
Scientific softwares – ROOT, ROOFIT, GEANT4, MATLAB, Mathematica, ALTIUM, LabVIEW and LaTeX.
Machine Learning packages – TensorFlow/Keras

AWARDS AND HONORS

March 2017 – Won the Intensity Frontier Fellowship from Fermilab to spend 12 months at Fermilab to develop software algorithms for the software-based trigger of the Mu2e experiment and to prepare the calorimeter laboratory at Fermilab for the assembly.
December 2016 – Ranked in the list of the eligible candidates (but not hired) by the INFN selection for 58 esearchers level III at the national level (bando n. 18221/2016).
Ocotber 2015 – Won an award from the University Research Association (URA)[1]

[1] URA is a consortium of 89 leading research oriented universities primarily in the United States, with members also in Canada, Japan, Italy, and the United Kingdom. The not-for-profit URA

for spending 3 months at Fermilab developing, in cooperation with the Mu2e software group, a new method for measuring the number of stopped muons. We used the reconstruction of low-energy (few MeV) protons generated in the muon nuclear capture events (Grant 15-S-21).
September 2014 – Won the "Best Presentation" award during the parallel HEP session at the 100$^{\text{th}}$ National Congress of the Italian Physics Society.
April 2014 – Won an award from URA, for spending 3 months at Fermilab developing a pattern recognition algorithm for the Mu2e experiment (Grant 14-S-08).

Service experience

Since July 2021 – Active in the ATLAS Trigger Menu performing on-call experts shifts. This activity ramped up with the official data taking start on July 2022.
March 2021, March 2023 – Member of the US ATLAS Diversity & Inclusion committee. This committee works to provide educational opportunities to U.S. ATLAS Members on the topics of equity, diversity and inclusion, and explores ways that U.S. ATLAS can develop a more equitable, welcoming and inclusive climate.
September 2020 – Organized and co-chaired the Mu2e-II TDAQ workshop for discussing with experts from various world-leading experiments the possible TDAQ designs for Mu2e-II. This event gave us a lot of insights about the different solutions. These have been particular important for outlining the R&D planning of the TDAQ subgroup.
October 2019 - January 2020 – Member of the Mu2e speakers committee.
Since June 2019 – Member of the organizing committee for the Yale PostDoc Symposium.
Since 2019 – Co-proponent and co-leader of the working package 5 (CLFV physics: data analysis) of the European project INTENSE: particle physics experiments at the intensity frontier. A cooperative Europe-US effort (GA 858199-H2020-MSCA-ITN-2019)
October 2018 – Co-chaired the TDAQ panel at the Mu2e-II workshop where we identified and discussed the expected requirements and challenges of the TDAQ system for the Mu2e-II experiment.
Since 2018 – Co-proponent and co-leader of the working package 4 (CLFV experiments) of the European project INTENSE: particle physics experiments at the intensity frontier. A cooperative Europe-US effort (GA 822185-H2020-MSCA-RISE-2018)
May 2017 – Co-chair at the calorimetry session during the International Conference on Technology and Instrumentation in Particle Physics 2017(TIPP2017) held in Beijing (China).
Since 2016 – Co-proponent and co-leader of the working-package 6 (FNAL Muon Campus experiments) of the European project NEWS (GA 734303-H2020-MSCA-RISE-2016)

Mentoring experience

Since June 2023 – Mentor of 2 Yale undergraduate working on the development of new Trigger algorithms for Mu2e.

Since June 2022 – Mentor of 3 graduate students working on ATLAS supporting them in the data analyses (Run2 $H \to \tau\tau$ STXS/VBF dirrential measurement and the Tau+X with the Run 2+3 datasets) projects and their qualification tasks.

Since May 2022 – Mentor of 2 undergraduate students from Yale working on new trigger algorithms to select events needed for the tracker performance studies and also on the development of the detector monitoring system within the TDAQ frame-

corporation was founded in 1965 for management and operation of research facilities in the national interes. Source: http://www.ura-hq.org

work.

Since May 2021 – Mentor of 1 graduate student from Yale working on the development of track triggers for Mu2e. More specifically, the student started working on fast track reconstruction strategies that will enable backup triggers for the experiment.
October 2020 - September 2021 – Mentor of 3 undergraduate students from Yale working on the development of Mu2e Trigger algorithms and improvements of the Mu2e Online tracking performance.
June 2020 - August 2020 – Mentor of 3 undergraduate students from Yale working on the Mu2e online tracking algorithms and the development of new trigger algorithms, and 1 student from Michigan University working on the data-quality monitor of the Mu2e tracker.
May 2020 - Setember 2021 – Mentor 1 graduate student from Michigan University working on the Mu2e Cosmic-ray track reconstruction, trigger and background estimate.
June 2019 - August 2019 – Mentor of 1 graduate student and 4 undergraduate students from Yale for summer projects on the Mu2e Trigger system and tracking code.
September 2018 - June 2019 – Mentor of 3 undergraduate students from Yale working on the Mu2e Trigger system.
October 2014 - October 2017 – Co-supervisor of a graduate student, Raffaella Donghia, from University of Roma 3; thesis title "The Mu2e calorimeter: R&D and calibration strategies".
April 2018 - November 2018 – Co-chair of the Muon Department Journal club of Fermilab.
February 2018 - November 2018 – Mentor of one Yale graduate student working on the Mu2e Trigger system
June 2018 - August 2018 – Mentor of 3 undergraduate students selected in Yale for summer projects on the Mu2e Trigger system.
Since 2015 – Co-mentor of Summer students at Fermilab assigned to work on the Mu2e experiment with Dr. Pavel Murat.
2014 – Co-supervisor of an Electrical Engineering master student who worked on the development of an automatized test station for the photosensors for the calorimeter of the Mu2e experiment[2].

Teaching experience

October - December 2020 – Attended the course Equity in STEM for All Genders organized by the CIRTL network.
September 2020 – Attended the workshop Bring An Inclusive Mindset to your Teaching organized by the CIRTL network.
September - October 2020 – Attended the 6-week workshop Scientific Teaching Short Course organized by Macmillan Learning and The Summer Institutes for Scientific Teaching.
June 2020 – Named "Scientific Teaching Fellow" in recognition of demonstrated commitment to undergraduate education by participating in the CIRTL Summer Institute on Scientific Teaching.
June 2020 – Obtained the "Certificate of Completion" of the Johns Hopkins Teaching Institute
April 2019 – Obtained the "Certificate of College Teaching Preparation (CCTP)", thus Associate of the Center for Integration of Research, Teaching and Learning (CIRTL).
April 2019 – Lecture entitled "Charged Lepton Flavor Violation: an overview" for the course "Introduction to Elementary Particle Physics" held by Prof. Oliver Baker (oliver.baker@yale.edu) for the Yale Physics graduate school.
May 2019 – Completed the Spring 2019 CIRTL Network MOOC, "Advancing Learning Through Evidence Based STEM Teaching", with distinction.

[2] Thesis web link: https://etd.adm.unipi.it/theses/available/etd-09032014-113320

Since September 2018 – Attended a series 14 of Advanced Teaching Workshops (ATW) organized by the Center for Teaching and Learning at Yale: (1) Rubrics and Grading, (2) First-Generation and Non-Traditional Students, (3) Classroom Observation Workshop, (4) Creating and Maintaining Accessible Course Materials, (5) Inclusive Assessment Practices, (6) Teaching and Mentoring in the Lab Environment, (7) Teaching Naked, (8) Fundamentals of Teaching, (9) Fundamentals of Teaching in the Social Sciences, (10) Using Technology to Get Feedback on Teaching, (11) Teaching as an International Instructor, (12) How we learn, (13) Quiet Teaching, (14) Fostering Community in the Digital Classroom.
November 2018 – Completed the Fall 2018 CIRTL Network MOOC, "An Introduction to Evidence-Based Undergraduate STEM Teaching", with distinction.
November 2018 – Lecture entitled "The Mu2e experiment at Fermilab: a search for lepton flavor violation" for the course "Introduction to Nuclear Physics" held by Prof. Bonnie Fleming (bonnie.fleming@yale.edu) and Prof. Karsten Heeger (karsten.heeger@yale.edu) for the Yale Physics graduate school.
July 2018 – Lecturer for the "Mu2e summer lecture series" organized at Fermilab for the summer interns.
2015-2016 – Assistant of Prof. Guido Tonelli (guido.tonelli@pi.infn.it) in the General Physics class at the Engineer Department of the University of Pisa.
2012-2013 – Assistant of Prof. Franco Ligabue (f.ligabue@sns.it) in the General Physics class at the Engineer Department of the University of Pisa.

Outreach

Since Decemeber 2020 – Served as judge in the ENVISION high school competition for promoting women in STEM
March 2019 – Volunteer at the Connecticut Students Exploring Engineering Day (https://www.engineeringday.com/ctseed/)
June 2018 – Elevator talk on the Mu2e experiment at the 1st Yale Postdoctoral Symposium, New Haven (CT, USA).
September 2016 – Participated in the organization of the "European night of research" organized by the University and INFN of Pisa.

Scientific leadership

Since November 2023 – Deputy-coordinator of the Mu2e DAQ group. This position, together with the DAQ convener, is responsible for leading the development of the TDAQ sytem.
May - July 2023 – Member of the "Mu2e DAQ" task force to make a plan for getting to data-taking. What needs to be done, an estimate of the resources (both people and money) needed, and an overall design. This includes also the organization of the necessary subgroups to carry out the plan in each sub-system.
Since March 2024 – Trigger Menu and performance co-coordinator for the ATLAS experiment. This coordinator is responsible for: (i) reporting to Trigger Coordination, member of Trigger Management; (ii) representing in Physics Coordination the various Trigger performance groups; (iii) overseeing the work in the trigger signature groups and organise regular Signature Coordination Group meetings for discussion between Signature Coordinators and to ensure adequate planning, prioritization and execution exists within each signature group for algorithm developments and optimization, calibration, validation and trigger efficiencies studies; (iv) Organizing Menu/Performance Coordination Group meetings involving representation from Signature, Physics and Detector groups. Within the framework of this group: Receive and discuss requests for new/modified trigger items, rate sharing, stream definitions, pre-scales, etc. Plan and prioritize trigger efficiency estimates and other performance studies. Plan and prioritize the readiness of triggers and algorithms for online deployment; (v) ensuring proper trigger recommendations for data analysis; (vi) coordinate the work of the Trigger Rates group ensuring proper rate estimations are available for different conditions and associated tools to provide views/comparisons; (vii) coordinating the work amongst the menu-experts; (viii) Organize on-call support for menu expert tasks for trigger operations; (ix) coordinate requests for data

production for trigger studies (together with Releases & Validation coordinators); (x) ensuring optimized performance for deployed triggers; (xi) Defining and enforcing a procedure for introducing new algorithms and triggers in the menu, to deploy online (together with Trigger Operation coordinators).
November 2023 – Project investigator of a neutron irradiation test with 10^{14} neutrons/cm^2 for qualifying a reduced scale prototype of an electromagnetic calorimeter for the detector at the Muon collider facility within the RadNext H2020 infrastructure project.

January 2022 - March 2024 – Tau Trigger co-coordinator for the ATLAS experiment. This coordinator is responsible for: (i) involving and recruiting all collaborators interested in trigger development and studies and organise weekly or fortnightly meetings involving all relevant people in ATLAS, (ii) coordinate the development of the High-Level-Trigger algorithms (including bug fixes, required upgrades, new feature requests), their performance optimizations, including trigger performance, optimizations with respect to CPU, memory usage, data access and other resource needs (Trigger performance optimizations include for example improving selection requirements, determination of optimized calibration constants for online use to improve trigger performance.), (iii) signature strategies and definitions, (iv) Online and offline operations, which includes monitoring the performance of triggers online and associated data quality assessment, understanding the behaviour of triggers in debug streams and providing on-call experts to be available for daily operations.
April 2022 – Project investigator of a neutron irradiation test with 10^{14} neutrons/cm^2 for qualifying the SiPM candidates of the Crilin calorimeter prototype (R&D for an electromagnetic calorimeter for the detector at the Muon collider facility) within the RadNext H2020 infrastructure project.
October 2021 - February 2022 – Express stream coordinator for the ATLAS experiment. The Express Stream Coordinator is responsible for defining the express stream menu, which provides the data used in the initial Data Quality assessment. This position reports to the DataPrep coordinators and works in close collaboration with the Data Quality group. The Express Stream Coordinator is also a member of the Trigger Menu Coordination Group which ensures good communication with the Trigger group. Specific responsibilities are: (i) Understanding the monitoring needs of the various DQ communities (detector, CP/physics groups), (ii) understanding the other calibrations uses of the express stream (e.g.: beamspot, LAr noise bursts), (iii) designing an express stream menu which meets these needs while staying within the bandwidth budget, (iv) keeping up to date with developments and changes in the trigger menu which effect the express stream, (v) periodic review to see if changes are needed, including changes due to increasing luminosity, detector conditions, monitoring needs, etc and (vi) monitoring of the actual express stream bandwidth to ensure that the bandwidth targets are being met.
Since July 2020 – Co-convener of the Mu2e-II TDAQ subgroup (10-15 people from more than 6 different institutes) where we started discussing multiple solutions that can fit the Mu2e-II requirements. The first deliverable of the group is represented by the three Letter Of Interests that we submitted to the Snowmass2020 process. The next phase of the group activity will focus on developing simplified test of algorithm implementation on FPGA using the High Level Synthesis tool (HLS) and also GPUs.
Since February 2020 – Co-convener of the ATLAS Tau Reco&ID subgroup (10-15 people from more than 8 different institutions) that is focused on improving our current algorithms and developing new ones for the Run 3 and the High-Luminosity challenges.
September 2019 - November 2023 – Co-coordinator of a group of 2 graduate students from Yale working on the $VH,\ H \to \tau\tau$ data analysis with the full Run 2 dataset at ATLAS. I also developed the modeling of the background from jet faking taus and light leptons by means of the fake-method and I developed all the fit and systematic studies used to deliver the final results. My contribution allowed the group to achieve a good modeling of the data with our Monte Carlo. This was a

crucial steps towards the finalization of the analysis that was achieved on November 2023 with the approval of the analysis results. The paper will be submitted the first week of December 2023.
Since November 2018 – Co-convener of the Mu2e Trigger group (15-20 people from more than 10 institutes) where I have been giving a leading contribution in coordinating the activities towards the implementation of a TDAQ prototype that is currently used by the detector sub-groups for various slice-tests. I also put significant effort in supporting the activities of students, postdocs and senior scientists from various institutions (Yale, Michigan Univ, INFN, Pisa Univ).
Since September 2018 – Responsible for the development and customization of the Mu2e DAQ software interface that controls the Trigger tables and the event-builders of the DAQ farm.
Since May 2018 – Responsible for the development of the Mu2e Trigger Menu. I have been coordinating a large group of students from Yale that worked on improving the expected rejection performance and also designing new trigger lines. All the students delivered impressive results: we improved the background rejection by more than an order of magnitude and we also implemented a various number of studies for estimating the expected trigger rated of physical processes.
May 2017 – Responsability for the simulation and co-responsability for the reconstruction and analyses of the beam test for a large scale Mu2e calorimeter prototype, made of pure CsI coupled with custom Silicon Photomultiplier (SiPM), at the Beam Test Facility in Frascati (Italy).
November 2016 - February 2017 – Co-responsability for the quality-assurance tests of the SiPM pre-production for the Mu2e calorimeter at the INFN of Pisa.
April - November 2015 – Responsability for the simulation and co-responsability for the reconstruction and analyses of the beam test for a reduced scale Mu2e calorimeter prototype, made of pure CsI coupled with Silicon Photomultiplier (SiPM), at the Beam Test Facility in Frascati (Italy).
July 2015 – Co-responsability for the radiation test with a neutron source at the FNG facility of the ENEA Institute in Frascati (Italy) on SiPM from several vendors, pure CsI crystals and components of the waveform digitizer board developed at the INFN of Pisa.
September - December 2014 – Responsability for the simulation and co-responsability for the reconstruction and analyses of the beam test for a Mu2e calorimeter prototype, made of LYSO crystals coupled with avhalanche-photodiodes (APD), at the Mainz microtron facility MAMI (Mainz, Germany), and at the Beam Test Facility in Frascati (Italy).

Public Talks

June 2023 – Presentation titled *Searches for charged lepton flavor violation in ATLAS and CMS* at CLFV2023 conference, Heidelberg (Germany)
May 2023 – Presentation titled *Future conversion search experiments* at the Muon4Future workshop, Venice (Italy).
March 2023 – presentation titled *Mu2e-II TDAQ summary* at the Workshop on a Future Muon Program At Fermilab, Caltech, Pasadena, CA (USA).
February 2022 – presentation titled *Search for rare and lepton flavor violating decays of the Higgs boson with the ATLAS detector* at the Lake Louise Winter Institute 2022 conference, Lake Louise (Canada).
November 2021 – presentation titled *Lepton Flavor Universality measurements* at the CKM2021 conference, Melbourne (Australia).
September 2021 – presentation titled *Status of the Mu2e-II experiment at Fermilab* at the TAU2021 conference, Bloomington (IN, USA).
September 2021 – presentation titled *The Mu2e experiment at Fermilab* at the NuFact2021 conference, Cagliari (Italy).
October 2020 – presentation titled *"Tau CP report"* at the ATLAS Collaboration week.
October 2020 – presentation titled *"The RNN-based Tau eVeto"* at Tau and HLeptons Workshop.

April 2020 – presentation in the plenary session, titled *"The track finder algorithm for the Trigger system of the Mu2e experiment at Fermilab"* at Connecting The Dots 2020, 6th International Workshop, Princeton (NJ, USA).
July 2019 – seminar titled *"The Mu2e experiment"* for the LHC Physics Center Forum at Fermilab, Batavia (IL, USA).
June 2019 – presentation in the plenary session, titled *"Mu2e: a search for charged lepton flavor violation"* at the CLFV2019 : The 3rd International Conference on Charged Lepton Flavor Violation, Fukuoka (Japan).
January 2019 – seminar titled *"Mu2e: A Search for Charged Lepton Flavor Violation in* $\mu^- \mathrm{N} \rightarrow \mathrm{e}^- \mathrm{N}$ *conversion with a Sensitivity ¡* 10^{-16}*"* for the Weak Interaction Discussion Group of the Wright Laboratory at Yale, New Haven (CT, USA).
July 2018 – presentation in a parallel session, titled *"The Mu2e Tracker"* at the XXXIX International Conference of High Energy Physics 2018(ICHEP2018), Seoul (South Korea).
July 2018 – presentation in a parallel session, titled *"Mu2e: a search for charged lepton flavor violation"* at the XXXIX International Conference of High Energy Physics 2018(ICHEP2018), Seoul (South Korea).
June 2018 – presentation at the plenary session, titled *"The Mu2e experiment at Fermilab: a search for lepton flavor violation"* at the New Perspective conference at Fermilab, Batavia (IL, USA).
October 2017 – presentation of a poster, titled *"Quality Assurance on a custom SiPMs array for the Mu2e calorimeter"* at the Nuclear Science Symposium, Atlanta (GA, USA).
May 2017 – presentation in a parallel session, titled *"Design, status and perspective of the Mu2e crystal calorimeter"* at the International Conference on Technology and Instrumentation in Particle Physics 2017(TIPP2017), Beijing (China).
July 2016 – presentation in the plenary session, titled *"Mu2e calorimeter and combined detector performance"* at the Mu2e Collaboration meeting , Fermilab, Batavia (IL, USA).
June 2016 – presentation in a parallel session, titled *"Mu2e: an experiment to search for* $\mu \rightarrow e$ *coherent conversion"* at the International Sixth Workshop on Theory, Phenomenology and Experiments in Flavour Physics - FPCapri2016, Anacapri (Italia).
June 2016 – presentation in a parallel session, titled *"The Mu2e experiment at Fermilab"* at the 28^{th} edition of the international conference Rencontres de Blois, Blois (France).
November 2015 – presentation of a poster, titled *"The Calorimeter seeded Track Reconstruction for the Mu2e experiment at Fermilab"* at the Nuclear Science Symposium, S. Diego (CA, USA).
September 2014 – presentation in a parallel session, titled *"Photosensors test station for the Mu2e calorimeter"* at the National Congress of the Italian Physics Society, Pisa (Italia).
April 2014 – presentation in the plenary session, titled *"Progress status for the Mu2e Calorimeter system"* at CALOR2014, Geissen (Germania).
October 2013 – presentation in the plenary session, titled *"The LYSO crystal calorimeter for the Mu2e experiment"* at the international conference Innovative Particle and Radiation Detectors, Siena (Italia).
September 2013 – presentation of a poster, titled *"The* $\mu\ N \rightarrow e\ N$ *experiment at Fermilab"* at the international conference Pontecorvo100, Pisa (Italia).
September 2013 – presentation of a poster, titled *"Cosmic background rejection by means of the calorimeter in the Mu2e experiment at Fermilab"* at the internation confernece Charge Lepton Flavour Violation, Lecce (Italia).

Research activity

DATA ANALYSIS **ATLAS Legacy search for the non-resonant production of Higgs boson**

pairs via gluon fusion and vector-boson fusion in the $b\bar{b}\tau^+\tau^-$ final state Since May 2023 – Memeber of the editorial board of the legacy search for the non-resonant production of Higgs boson pairs via gluon fusion and vector-boson fusion in the $bb\tau\tau$ final state in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector.

ATLAS Run 2 Higgs Lepton Flavor Violation analysis 2019-2023 – I joined the analysis group that is currently working on performing the analysis with the full Run 2 dataset. This analysis is divided into two main channels based on the decay mode of the tau: $H \to e/\mu\ \tau_{lep}$ (lep-lep) and $H \to e/\mu\ \tau_{had}$ (lep-had). I have been actively involved in the (lep-had) channel, where I have been working with one of the co-convener of the analysis in the two main parts: (1) the so called "acceptance-challenge" for understanding/validating the result of the pre-selection cut-flow and (2) the data-driven estimate of the Z $\to$ ee background. The Monte-Carlo based approach of this background is characterized by a large uncertainty due to the limited statistic available of the $Z + jets$ sample. I was one of the editor of the paper that was submitted for pubblication on February 2023.

ATLAS Run 2 Higgs boson production in association with a vector boson and decaying into a tau pair Since April 2019 – This analysis is leaded my group at Yale, where we have two graduate students fully devoted to the analysis. This analysis has been categorized into four different channels: $ZH, H \to \tau_{lep}\tau_{had}$ $ZH, H \to \tau_{had}\tau_{had}$ $WH, H \to \tau_{lep}\tau_{had}$ and $WH, H \to \tau_{had}\tau_{had}$. My contribution has been focused on developing the Fake method in the four categories for estimating the background contribution from Jets mimicking the signature of a tau decaying hadronically (τ_{had}) or leptons (e/μ). This represents the major background of the analysis. My method has been validated with a dedicated control region that requires the same charge of the particles associated to the Higgs decay. This control region is expected to be fake-dominated and thus represents a powerful test for validating the fake model implemented. In addition to that, I have been advising the graduate students that are more focused in the other parts of the analysis: optimization of the cut-flow analysis, development of a Neural-Network for the rejection of the background from di-boson and final cross-section measurement. I've been the analysis contact and editor of the paper that is finalized and will be submitted to Physics Letters B the first week of December 2023.

Software development

ATLAS Trigger Menu development for the ATLAS Run 3
Since August 2020 – I joined the Trigger Menu Experts group. My activity has been focused on implementing infrastructural upgrades of the software infrastructure necessary for Run 3. I have developed a flexible tool that can apply topological cuts using inputs from different trigger legs. This was particularly important for supporting the development of new trigger chains that can improve the efficiency of several signal searches.

Tau electron veto for the ATLAS Run 3
Since April 2019 – I developed an improved electron veto for true electrons misidentified as hadronic taus for Run 3. The current tau electron veto is using a boosted decision tree (BDT), which uses transition radiation (TR) information from the Transition Radiation Tracker (TRT) and calorimeter cluster information for 1-prong tau candidates. The TRT will probably be operated with a different gas mixture in Run 3, which will provide reduced particle ID capabilities and thus the calorimeter information will become more important to distinguish e from π. The algorithm I developed is based on a Recurrent Neural Network (RNN) that includes low level info from the tracks and the clusters associated to the tau jet. The results I obtained proved that the rejection power can be improved significantly by at least a factor x5 (comparing the rejections at the same working points). In addition to that, the RNN algorithm showed to be more robust against the occupancy w.r.t. to the predecessor BDT. I was capable to provide also a dedicated tuning for the

3-prong case that instead was not available in the BDT case, which was tuned only for the 1-prong case. The preliminary version of this algorithm was integrated in the release 22 of the ATLAS reconstruction code. Additional studies are ongoing to further improve the performance.

Mu2e Trigger test stand

Since 2018 – I have been working on the development of the customized version of "Off-The-Shell" software (OTS)[3] for the Mu2e experiment. I am one of the leaders of the R&D of this software. I have been providing a strong contribution in delivering the current TDAQ prototype and developing the horizontal slice test used to measure the expected performance of the Trigger farm. I've performed several optimization studies using profiling softwares (Valgrind and VTune) that allowed to improve considerably the timing performance. These studies allowed to bring the timing performance of the online reconstruction below the Mu2e requirement (with a 30% of safety margin). This work has been used also by the sub-detector groups for their slice tests. Part of my development was also integrated in the core software of OTS.

Trigger algorithms in Mu2e

June 2018 - September 2020 – I developed, with the help of my mentees, two track-based trigger lines for providing two calibration datasets for the Tracker. These triggers select e^- or e^+ coming from the muon decay-in-orbit (or decay at rest for the e^+ case) that in Mu2e are expected to happen during the nominal runs in the Inner proton absorber, which is located between the Al Stopping Target and the Tracker. The geometrical configuration of this absorber allows these e^-/e^+ to fall into the fiducial volume of the tracker. The resulting reconstructed momentum spectra represent a valuable reference to set the tracker momentum scale and also monitor it during the data taking.

Since 2017 – I have been working within the Mu2e Trigger group on the improvement of the Mu2e trigger algorithms. I gave significant contribution in designing the track-based triggers of the experiment used to select events with a CLFV signal candidate.

2016 – I developed, within the Mu2e Fermilab group, an algorithm that combines the information of the tracker and the calorimeter to implement a track search. This resulted in an efficiency of about 95% for the signal, and a background rejection factor larger than 200. I also developed, within the Pisa group, an algorithm that relies only on the calorimeter information to provide a fast trigger.

Algorithms for track reconstruction in Mu2e

Since 2018 – I started working on the improvement of the pattern-recognition algorithms to improve their physics performance in terms of background rejection power and robustness in the reconstruction efficiency. I gave a large contribution to developing, with my mentees, improvements that allowed to reconstruct low-energy particles ($p \in [40, 80]$ MeV/c). This feature enabled a series of progress in the calibration and beam-monitoring studies. This work has been rather important as the performance of the pattern recognition algorithms drive the efficiency of the track-based Triggers.

Since 2016 – I started working within the Mu2e Tracking group on improving the current schema of the Kalman-base fitter algorithm. The changes I am introducing will allow to: 1) improve the low energy proton track reconstruction performance, 2) migrate to a kinematic fit where the time of the hits is explicitly taken into account, 3) the calorimeter cluster is included as an hit also in the Kalman-based track fit.

2015 – I developed, within the Fermilab and Lawrence Berkeley National Laboratory groups, an algorithm for resolving the left-right ambiguity in the Mu2e track reconstuction software. This algorithm allows to improve the momentum resolution and the track reconstruction efficiency. For an experiment like Mu2e, the control and the understanding of the momentum resolution tails is of particular importance.
I also performed a preliminary study for a dedicated track-search algorithm that

[3] Kurt Biery, *et al*, "artdaq: DAQ software development made simple"

would allow to reconstruct low-energy proton tracks in Mu2e. These protons are originated in the muon capture process, so their reconstruction would allow to perform a measurement of the number of muon capture events. This number represents the normalization factor of the Mu2e measurement.

A calorimeter-seeded track search algorithm
2013 – I developed, within the Mu2e Fermilab group, an algorithm for the track search that uses the calorimeter information for seeding the track search. This algorithm provides a momentum resolution of about 5% for e^- with 105 MeV/c in 1 Tesla magnetic field. Moreover, this algorithm provides an improvement in the Mu2e track reconstruction efficiency of the order of 15% and makes the track reconstruction more robust.

Algorithm for Particle Identification
2012 – I developed, within the Mu2e Fermilab group, an algorithm that provides particle-identification capabilities. This algorithm combines the reconstructed track and the calorimeter information. Simulation studies showed that this algorithm is important for rejecting two relevant background sources:

- atmospheric μ that can interact in the detector region and get trapped in the magnetic field;
- μ and π produced via the annhilation of the $\bar{p}$ in the Mu2e target.

Simulation studies showed that a calorimeter with a timing resolution bettern than 500 ps and an energy resolution better than 5% at 105 MeV provides the required rejection factor, while keeping the electron identification efficiency larger than 96%.

Calorimeter simulation
Since 2012 – I participated, with the Caltech group, on the development of the calorimeter simulation with the Mu2e Offline software. This allowed to perform an optimization of the calorimeter geometry, to study the expected dose, and neutron flux. I also contributed in the development of the reconstruction algorithms, for example the clustering and the track-to-cluster matching algorithms, as well as the calibration routines by means of Cosmic rays.

Calorimeter digitization
2015 – I developed, cooperating with the LNF-INFN, Caltech and the Fermilab groups, an algorithm to simulate the signal digitization performed by the Mu2e calorimeter digitizer boards. The main role of the digitizer boards is to provide pile-up separation capabilities and also a timing resolution of a few hundreds of ps. A first prototype of the waveform digitizer board is under construction at the INFN of Pisa.

Sensitivity
2015 – I participated with the Mu2e Fermilab group on the sensitivity studies. I also quoted the expected sensitivity of the Mu2e experiment using the CLs method[4].

Hardware activity

Automated test station for SiPM
2016-2018 – Improved the photosensor test station, developed at the INFN of Pisa, to operate with the new technology adopted by the Mu2e calorimeter (from LYSO crystals + APD, to pure CsI + SiPM). The final photosensor design consisted of a custom array of SiPM that allows to have a large active area. Moreover a low capacitance (order of nF) is provided just by connecting the SiPM in series. This allows to have short pulses (about 150 ns), which improves the pile-up separation capability. I developed within the Pisa group measurements for characterizing several prototypes

[4] T. Junk, "Confidence level computation for combining searches with small statistics". NIM A 434, 435 – 443 (1999)

of these array of SiPM, and we also developed a full-automated system for measuring the dark current and the gain in a temperature-controlled environment under vacuum. We also commissioned the whole system at the QA calorimeter laboratory at Fermilab.

Qualification of the most relevant components of the Mu2e calorimeter
2015 – Several radiation tests have been performed on crystals, photosensors, DCDC-converter and ADC selected for the waveform digitizer board. Crystals were exposed up to 90 krad of dose and a fluence uo to 10^{12} n/cm^2, while the photosensors and the digitizer components were exposed up to 20 krad of dose and a fluence up to 3×10^{11} n(1 MeV-eq)/cm^2. We confirmed that the pure CsI crystals are sufficiently rad-hard up to the dose and the neutron flux expected in the Mu2e experiment. For the photosensors we observed that they are insensitive up to 20 krad of dose, while they showed a rise in the dark current by a factor of 2000 after exposed to neutrons. The solution we opted for in the Mu2e experiment is to cool their temperature down to 0^{o}C to reduce the dark current. For the DCDC-converter and the ADC we observed no significant variation in the behaviour.

Beam test for Calorimeter prototypes
May 2017 – We tested a small-scale prototype, made of 51 pure CsI crystals $3.34 \times 3.34 \times 20$ cm^3, coupled with SiPM UV-extended, at the Beam Test Facility in Frascati (Italy). This large prototype was built with a mechanical structure + cooling system similar to the one that will be employed in the full scale calorimeter. I coordinated the Analyses group that obtained excellent results: an energy resolution of 6% and a timing resolution of about 100 ps at 100 MeV.
April 2015 – We tested a small-scale prototype, made of 9 pure CsI crystals $3 \times 3 \times 20$ cm^3, coupled with SiPM UV-extended, at the Beam Test Facility in Frascati (Italy). I personally performed the performance analyses as part of my Ph.D. thesis. We obtained excellent results: an energy resolution of 7% (due to the lateral leackage) and a timing resolution of about 120 ps at 100 MeV.
2014 – We tested a prototype of 25 LYSO crystals, coupled with APD, equipped with a laser system (a web of optical fibers linked to each photosensor) for monitoring the gain variations. We performed two tests: in September 2014 using tagged photons at the Mainz microtron, and in November 2014 at the Beam Test Faicility in Frascati by means of an electon beam. We measured an energy resolution of 4.4% and a timing resolution of 150 ps at 100 MeV.

Selected papers

Selected papers

Evidence for the $VH, H \to \tau\tau$ process with the ATLAS detector in Run 2 – ATLAS Collaboration arXiv:2312.02394 (submitted on Phys. Let. B). This analysis searches for the Standard Model Higgs boson produced in association with a W or Z boson and decaying into a pair of τ-leptons. This search is based on proton-proton collision data collected at $\sqrt{s} = 13$ TeV by the ATLAS experiment at the LHC corresponding to an integrated luminosity of 140 fb^{-1}. For the Higgs boson candidate, only final states with at least one τ decaying hadronically ($\tau \to$ hadrons+ν_τ) are considered. For the vector bosons, only leptonic decay channels are considered: $Z \to \ell\ell$ and $W \to \ell\nu_\ell$, with $\ell = e, \mu$. An excess of events over the expected background is found with an observed (expected) significance of 4.2 (3.6) standard deviations, providing evidence of the Higgs boson produced in association with a vector boson and decaying into a pair of τ-leptons. The ratio of the measured cross-section to the Standard Model prediction is $\mu_{VH}^{\tau\tau} = 1.28\ ^{+0.30}_{-0.29}$ (stat.) $^{+0.25}_{-0.21}$ (syst.).

Searches for lepton-flavour-violating decays of the Higgs boson into $e\tau$ and $\mu\tau$ in $\sqrt{s} = 13$ TeV pp collisions with the ATLAS detector – ATLAS Collaboration JHEP 07 (2023) 166 (2023). This paper presents direct searches for lepton flavour violation in Higgs boson decays, $H \to e\tau$ and $H \to \mu\tau$, performed using data collected with the ATLAS detector at the LHC. The searches are based on a data sample of proton–proton collisions at a centre-of-mass energy $\sqrt{s} = 13$ TeV, corresponding to an integrated luminosity of 138 fb^{-1}. Two background estimation techniques are exploited: the MC-template method, based on data-corrected simulation samples, and the Symmetry method, based on exploiting the symmetry between electrons and muons in the standard model backgrounds. No significant excess is observed and the results are interpreted as upper limits on lepton flavour violating branching ratios of the Higgs boson. The observed (expected) upper limits at 95% confidence level on the branching ratios of $\mathcal{B}(H \to e\tau) < 0.19\%$ (0.11%) and $\mathcal{B}(H \to \mu\tau) < 0.18\%$ (0.09%) are obtained with the MC-template method from the simultaneous measurement of the $H \to e\tau$ and $H \to \mu\tau$ signals. The best-fit branching ratio difference, $\mathcal{B}(H \to \mu\tau) - \mathcal{B}(H \to e\tau)$, measured with the Symmetry method in the channel where the tau decays to leptons, corresponds to $0.25 \pm 0.10\%$. I worked as one of the editors of this paper and I also focused on studying the $l\tau_{had}$ channel ($l = e,\ \mu$) with particular emphasis to the background from Drell-Yan $Z \to ee$ events.

Mu2e Run I Sensitivity Projections for the Neutrinoless $\mu^- \to e$ Conversion Search in Aluminum – Mu2e Collaboration arXiv:2210.11380 (2021). The Mu2e experiment at Fermilab will search for the neutrinoless $\mu^- \to e^-$ conversion in the field of an aluminum nucleus. The Mu2e data-taking plan assumes two running periods, Run I and Run II, separated by an approximately two-year-long shutdown. This paper presents an estimate of the expected Mu2e Run I search sensitivity and includes a detailed discussion of the background sources, uncertainties of their prediction, analysis procedures, and the optimization of the experimental sensitivity. The expected Run I 5σ discovery sensitivity is $R_{\mu e} = 1.2 \times 10^{-15}$, with a total expected background of 0.11 ± 0.03 events. In the absence of a signal, the expected upper limit is $R_{\mu e} < 6.2 \times 10^{-16}$ at 90% CL. This represents a three order of magnitude improvement over the current experimental limit of $R_{\mu e} < 7 \times 10^{-13}$ at 90% CL set by the SINDRUM II experiment. I was one of the editors of this paper and I gave relevant contributions in many areas of the analysis: the study of the expected trigger performance and the characterization of the background induced by atmospheric muons.

An induced annealing technique for SiPMs neutron radiation damage – M. Cordelli *et al.* JINST (2021). In this paper we proposed a novel method

for a fast annealing of SiPMs previously exposed to a neutron fluence of about 10^{12} $n_{1MeV-eq}/cm^2$. Our technique allowed us to reduce the leakage current of a factor ranging between 15-20 depending on the overbias used and the SiPM vendor. I gave a significant contribution in planning and conducting the test with colleagues at the SiDet facility at Fermilab. This technique proves that the performance loss of the SiPMs due to neutron damage can be partially recovered "on-site" if the system is equipped with a proper power system.

Applications and Techniques for Fast MachineLearning in Science – N. Tran *et al.*,(Big Data and AI in High Energy Physics) (2021). This paper presents a large variaty of applications of Fast Machine Learning techniques planned for future HEP experiments. I edited the section devoted to the applications in the Mu2e experiment and its planned upgrade (Mu2e-II). In the last year, we started investigating the possibility of implementing parts of the track-reconstruction used in the online reconstruction on FPGA using the High Level Synthesis tool (HLS).

"Vetoing electrons mimicking hadronic tau lepton decays using neural networks in the ATLAS experiment" – G. Pezzullo *et al.*, ATL-PHYS-PUB-2022-044 (2020). This note discuss the development of a novel algorithm, based on a Recurrent-Neural-Network, that vetoes electrons mimicking hadronic tau lepton decays. This new algorithm significantly improves the rejection performance compared to its predecessor by a factor ¿ x50 and in addition to that, it resulted to be more stable against the high pile-up events.

"The track finder algorithm for the trigger system of the Mu2e experiment at Fermilab" – D. Brown, G. Pezzullo and P. Murat, PROC-CTD2020-59 (2020). This paper presents the current expected performance of the Online track reconstruction algorithm used in Mu2e. The Online tracking is the central part of the Mu2e TDAQ system and in this paper we discuss also the preliminary results obtained with the prototype assembled at Fermilab. I gave a leading contribution in the design and optimization of the pattern-recognition algorithms as long as the development of the development of the software interface used to control the DAQ operations.

"The Mu2e Calorimeter Final Technical Design Report" – N. Atanov, *et al.*, arXiv:1802.06341 [physics.ins-det] (2018). This document represents the most extensive and updated description of the Mu2e calorimeter technical design. My contribution was significant from the simulation point of view and also the test beam analysis. The work I did on the simulation served to motivate the need of a calorimeter in the Mu2e design: particle-ID and supporting the tracking. Moreover, I implemented a large series of study meant to understand the performance requirements for the detector and the expected dose level.

"Expression of Interest for Evolution of the Mu2e Experiment" – F. Abusalma, *et al.*, arXiv:1802.02599 [physics.ins-det] (2018). This paper is the results of two workshops. In the latter one, I had co-chaired the TDAQ-Trigger session. We have been discussing the challenges for a "phase-II" scenario with upgraded detector and higher intensity beam. The track-trigger solution emerged as the most appealing an interesting solution.

"Pre-production and quality assurance of the Mu2e calorimeter Silicon Photomultipliers" – M. Cordelli, *et al.*, DOI:10.1016/j.nima.2017.12.039, NIM A, 0168-9002 (2017). This paper reports the preliminary results of the QA performed with my former Mu2e Pisa group over the SiPM employed in the calorimeter. We developed a fully automated test station capable to characterize the wafers of SiPMs in vacuum at different temperatures. My major contribution was the development of the data-acquisition and control systems.

"The calorimeter-seeded track reconstruction for the Mu2e experiment at Fermilab" – G. Pezzullo and P. Murat, DOI:10.1109/NSSMIC.2015.7581921, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 1-3, (2015). I gave significant contribution in developing the calorimeter-seeded pattern recognition for Mu2e. This algorithm is still part of the official online and offline reconstruction code. This algorithm is essential for Mu2e for achieving a trigger efficiency larger than 95%,while keeping the background rejection at the level of few thousands.

Measurement of the energy and time resolution of a undoped CsI + MPPC array for the Mu2e experiment – O. Atanova, *et al.*, DOI:10.1088/1748-0221/12/05/P05007, JINST **12**, 05, P05007 (2017). I participated to the test beam providing a significant contribution in the reconstruction code and the design of the data taking plan. Moreover, I leaded the data analysis effort by: (i) developing a new algorithm for the time reconstruction, (ii) proposing new methods for estimating the time resolution and (iii) implementing all the required calibrations. I also developed all the GEANT4 based Monte Carlo simulations that were used for the data analysis.

"Energy and time resolution of a LYSO matrix prototype for the Mu2e experiment" – N. Atanov *et al.*, DOI:10.1016/j.nima.2015.09.051, NIM A **824**, 684-685 (2016). I participated to the test beam providing a significant contribution. I gave a significant contribution in the data analysis effort and in the optimization of the reconstruction and calibration code. I developed all the GEANT4 based Monte Carlo simulations that were used for the data analysis.

Papers reviews

Papers reviews

2022 – Reviewer for NIM A

2020 – Reviewer for JINST

2018 – Reviewer for NIM A

2017 – Internal Mu2e reviewer for NIM A paper: Photoelectron yields of scintillation counters with embedded wavelength-shifting fibers read out with silicon photomultipliers, A. Artikov *et al.*, NIM A 890 (2018) 84-95

2017 – Reviewer for NIM B

2016 – Reviewer for JESTECH

Full list of papers

Published papers

- list of published papers

References

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Note legali

Il sottoscritto Gianantonio Pezzullo dichiara altresì di essere informato, ai sensi e per gli effetti di cui all'art. 13 del Decreto Legislativo 196/2003, che i dati personali raccolti saranno trattati, anche con strumenti informatici, esclusivamente nell'ambito del procedimento per il quale la presente dichiarazione viene resa.

St Genis Pouilly, March 24, 2024