

Roberto Zarrella

Curriculum Vitae

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Current Position

Nov. 2023 - **Research Associate**
present Alma Mater Studiorum University of Bologna,
Department of Physics and Astronomy “A. Righi”

Education

Nov. 2020 - **Ph.D. in Physics**
present Alma Mater Studiorum University of Bologna,
Department of Physics and Astronomy “A. Righi”

May - **Scholarship,**
Oct. 2020 University of Pisa, Department of Physics “E. Fermi”,
Scholarship title: *“Data analysis of the Time-Of-Flight detectors of the FOOT experiment for the identification of fragments in nuclear reactions of interest in hadrontherapy”*.

Sep. 2017 **Master degree in Physics, curriculum of Medical Physics**
- Apr. 2020 University of Pisa, Department of Physics “E. Fermi”
Master thesis: *“Charge identification of nuclear fragments with the Time-Of-Flight detectors of the FOOT experiment”*
Supervisors: Prof. Maria Giuseppina Bisogni, Dott. Aafke Christine Kraan
Final grade 110/110 cum laude.

Sep. 2014 - **Bachelor degree in Physics,**
Oct. 2017 University of Pisa, Department of Physics “E. Fermi”
Supervisor: Prof. Maria Giuseppina Bisogni
Final grade 109/110.

2009 - 2014 Secondary School Diploma, “Liceo Scientifico G. Torelli”, Fano
Scientific maturity.

Research activity

May 2019 **INFN Associate**
- Oct. 2020 Section of Pisa

During my master thesis and scholarship in Pisa I have worked on the development of the charge identification procedure utilized in the nuclear physics experiment called FOOT (FragmentatiOn Of Target). The main goal of FOOT is the measurement of the cross section of fragmentation processes relevant for hadrontherapy treatment planning and radioprotection in long term space missions. These high-precision cross section measurements will be performed by extracting the relevant properties of nuclear fragments produced in tissue-like targets by light ion projectiles (up to ^{16}O) at different energies (100-800 MeV/u).

My work concerned developing a signal processing framework and calibration procedure (C++/ROOT language) for the scintillating detectors of the experiment, dedicated to the charge identification of nuclear fragments through energy loss and Time-Of-Flight measurements. The results obtained through my master thesis work represent the first application of the charge identification procedure to fragmentation data acquired with the full ΔE -TOF system of FOOT.

Nov. 2020 **INFN Associate**
- present Section of Bologna

During my Ph.D. in Bologna I have finalized the work carried out in Pisa and published a dedicated paper in *Nucl. Inst. and Methods in Phys. Res. A* titled “*Charge identification of nuclear fragments with the FOOT Time-Of-Flight system*” during March 2021. In this work, we have demonstrated that the system is capable of measuring the Time-Of-Flight and energy loss of the produced nuclear fragments with a resolution better than 50 ps and of 4%, respectively, meeting the experimental requirements of FOOT in terms of fragment charge identification capabilities.

My research activity is now mainly focused on the development of the global event reconstruction software of FOOT, called SHOE (Software for Hadrontherapy Optimization Experiment), which is an object-oriented flexible framework based on C++/ROOT. In particular, I have developed the fragment track reconstruction algorithm currently employed in SHOE, based on a Kalman Filter and implemented through the GENFIT toolkit. The final goal of the particle tracking is to provide a full reconstruction and identification of the fragmentation processes observed with the FOOT setup and extract the momentum and angle of emission of each particle. In this sense, my work has mainly focused on the development of the possible track finding algorithms that could be employed in FOOT. I worked on both forward and backward tracking algorithms, most of which are based on 4th order Runge-Kutta-Nyström extrapolation inside a magnetic field. With the current implementation, I have shown that the momentum and angle of emission resolution achievable by the tracking system of FOOT are compatible with the experimental requirements.

As developer of SHOE, I have also worked on the data processing workflow on different levels, from low-level algorithm optimization to the first implementation of batch processing on the HTCCondor resources of CNAF Tier1 data center. As of today, I am the main developer of the tools used by the Collaboration for CPU-intensive data processing and large scale production.

In addition, I have contributed to the full inclusion of the ΔE -TOF system (made of two plastic scintillator detectors) in the global DAQ of FOOT, as well as to its calibration and full performance characterization in terms of energy and time resolution and of charge identification capabilities. I am part of various analysis groups, both working on Monte Carlo and on real data. In particular, I am involved in the analysis of the ΔE -TOF system, in simulation studies devoted to neutron detection and in the analysis focused on fragmentation cross section evaluation.

During my PhD, I have also actively participated in the data acquisition campaigns of FOOT carried out at the GSI (Darmstadt, Germany), HIT (Heidelberg, Germany) and CNAO (Pavia, Italy) facilities as data analysis and software expert, mainly developing and handling the data online monitoring software SLIPPER (Software for Live Interactive Plotting and Partial Event Reconstruction). The fast processing framework I have implemented was fundamental at HIT and at CNAO in order to tune the accelerator and beam line transport parameters, necessary to have a stable beam for the data taking. Moreover, the online processing made it possible to monitor the performance of all the FOOT detectors read-out by the WaveDAQ system, i.e. the ΔE -TOF system and the Calorimeter. This was fundamental to keep under control the time and energy resolution of the detectors over the whole data acquisitions.

I am also directly involved in the characterization of the neutron detectors of FOOT, which consist in two liquid scintillator telescopes (BC501-A) and a set of Phoswich BGO crystals. The final goal is to assess the n- γ discrimination capabilities of the available systems and measure their detection efficiency for fast neutrons over a wide energy range (1 MeV - 1 GeV). A Letter Of Intent, of which I am spokesperson, was received and approved by the ISOLDE and n_TOF Experiments Committee (INTC) to measure such detection efficiency at the n_TOF facility at CERN. A dedicated data acquisition campaign has been carried out between May and September 2022 in the Neutron Escape Line of n_TOF Experimental Area 1. The analysis of the acquired data is currently ongoing and I have presented the preliminary results at the 16th Topical Seminar on innovative Particle Radiation Detectors (IPRD23). This work will explore the possibility to extend the FOOT apparatus to include the measurement of neutron production cross sections in fragmentation reactions of interest for hadrontherapy and radioprotection in space.

Mar. 2022 **CERN Associate**
- Oct. 2022 at the n_TOF experiment

During my stay at CERN, as part of the n_TOF Local Team, I have also been actively involved in the experimental activities carried out at the n_TOF facility during the physics run of 2022. In addition to the work on the FOOT neutron detectors, I had the opportunity to follow several data acquisition campaigns devoted to the measurement of neutron-induced reaction cross sections, mainly of interest for nuclear astrophysics, medical applications and reactor technologies. I contributed to the mounting of several experimental setups, as well as to the following data quality monitoring at the facility.

I have also been involved in the analysis of the data acquired during the Commissioning of the 3rd n_TOF spallation target, which is dedicated to the evaluation of the neutron flux in the two Experimental Areas of the facility. In particular, I have been involved in the analysis of the Parallel Plate Avalanche Counters (PPACs), which exploit the neutron-induced fission of ²³⁵U and ²³⁸U to extract the neutron flux over a wide energy range (from thermal to 1 GeV).

Honors and Awards

- Sep. 2020 **Best oral contribution for the Biophysics and Medical Physics section at the 106th National Congress of the Italian Physics Society (SIF)**
Title of the contribution: “*Calibration and performances of the full scale ΔE -TOF system prototype of the FOOT experiment*”.
- Mar. 2020 Selected as winner for the scholarship “*La Fisica Nucleare nei Laboratori*” granted by the National Scientific Commission 3 (CSN3) of the National Institute for Nuclear Physics (INFN)
Not started due to the SARS-CoV-2 pandemic
- Jun. 2014 **Winner** of one of the scholarships granted by the *Fondazione Giuseppe Occhialini* for High School students.

Scientific responsibilities and coordination activities

- Sep. 2023 **Maintainer**
- present of the reconstruction and analysis software SHOE (Software for Hadrontherapy Optimization Experiment) of the FOOT experiment
- Sep. 2019 **Software Manager**
- present of the online analysis tool SLIPPER (Software for Live Interactive Plotting and Partial Event Reconstruction) of the FOOT experiment
- Jun. 2022 **Spokesperson** of the Letter of Intent
Report CERN-INTC-2022-020 “*Characterization of the FOOT neutron detectors for nuclear fragmentation measurements at the n_TOF facility*”.
Data acquisition performed in May-Sep. 2022
- Mar. - Oct. 2022 **CERN associate**
As part of the n_TOF Collaboration Local Team

Teaching activity

- Mar. 2024 - **Tutor** (Prot. n. 13673)
May 2024 of the course of Electromagnetism and Optics Laboratory for the Bachelor Degree course in Physics
Alma Mater Studiorum University of Bologna, Department of Physics and Astronomy
- 2021 - present **Co-Supervisor** of 3 Master Students
Alma Mater Studiorum University of Bologna, Department of Physics and Astronomy
- 2020 - present **Co-Supervisor** of 2 Bachelor Students
Alma Mater Studiorum University of Bologna, Department of Physics and Astronomy

Outreach activity

- Mar. 15, 2024 **INFN-IPPOG 20th International Masterclass on hands-on particle physics**
Local organizer/lecturer for the “Particle therapy” session in Bologna
- Mar. 14, 2023 **INFN-IPPOG 19th International Masterclass on hands-on particle physics**
Local organizer/lecturer for the “Particle therapy” session in Bologna

Schools

- Jan. 21-26 **The n_TOF Nuclear Physics Winter School 2024**
2024 Saint-Gervais-Les-Bains, France.
- Jul. 17-21 **2023 Physical Sensing and Processing Summer School**
2023 University of Bologna, Italy.
- Jun. 4-9 **XX Seminar on Software for Nuclear, Subnuclear and Applied Physics**
2023 INFN, Alghero, Italy.
- Aug. 29 - **ChETEC-INFRA Nuclear Physics in Astrophysics - X School**
Sep. 3, 2022 CERN, Geneva.
- Jul. 22-26 **Re-writing Nuclear Physics textbooks: one more step forward**
2019 INFN, University of Pisa, Italy.

Conferences

- Sep. 25-29, 2023 **16th Topical Seminar on innovative Particle Radiation Detectors (IPRD23)**
Talk: “*Characterization of the FOOT neutron detectors for nuclear fragmentation measurements at the n_TOF facility*”.
- Jul. 24-29, 2022 **15th International Conference on Nuclear Data for Science and Technology (ND2022)**, Online conference
Invited talk: “*Nuclear fragmentation cross section measurements with the FOOT experiment*”.
- Sep. 13-17, 2021 **107° Congresso Nazionale SIF**, Online conference
Invited talk: “*Particle tracking in the FOOT experiment*”.
- Sep. 14-18, 2020 **106° Congresso Nazionale SIF**, Online conference
Talk: “*Calibration and performances of the full scale ΔE -TOF system prototype of the FOOT experiment*”.

Computer skills

- Basic** Simulation framework FLUKA
Arduino programming tools
MATLAB
Software building tool CMake
Virtual Machine usage with Oracle VirtualBox
Code optimization and profiling with valgrind
Static source code control softwares (cppcheck, gdb)
Monte Carlo simulation toolkit GEANT4
Machine Learning with the Keras Python package
VHDL basics

Intermediate Microsoft Office tool Power Point (Office and OpenOffice)
Microsoft Office tool Excel (Office and OpenOffice)
Bash scripting language
HTCondor resources usage (also with basic DAG usage)
Docker image building and container usage
Operating systems Linux (Ubuntu, Fedora, SL, CentOs) and Windows
Data analysis language Python (matplotlib, scipy, numpy, pandas, multiprocessing)
Word processor language Markdown
Repository management and version control with Git
Pipelines creation for CI/CD in Git environment
Gitlab/Baltig pages integration
Code documentation with Doxygen

Advanced Data analysis framework ROOT
Object-oriented programming with C/C++
GenFit toolkit for particle track reconstruction
Microsoft Office tools: Word, Outlook
Word processor and document markup language L^AT_EX

Languages

Mothertongue Italian

Other English (Advanced understanding, writing and speaking)

May 2013 Cambridge ESOL First Certificate in English (FCE): European level C1

Other Spanish (Basic understanding, writing and speaking)

Publications

Articles

- M. Morrocchi et al., “Performance Evaluation of the TOF-Wall Detector of the FOOT Experiment”, in IEEE Transactions on Nuclear Science, doi: 10.1109/TNS.2020.3041433 (2020)
- G. Battistoni et al., “Measuring the Impact of Nuclear Interaction in Particle Therapy and in Radio Protection in Space: the FOOT Experiment”, in Frontiers in Physics, doi: 10.3389/fphy.2020.568242 (2021)
- A. C. Kraan, R. Zarrella et al., “Charge identification of nuclear fragments with the FOOT Time-Of-Flight system”, in Nuclear Instruments and Methods in Physics Research: Section A, doi: 10.1016/j.nima.2021.165206 (2021), **Corresponding author**
- G. Galati et al., “Charge identification of fragments with the emulsion spectrometer of the FOOT experiment”, in Open Physics, doi: 10.1515/phys-2021-0032 (2021)
- S. Colombi et al., “Enhancing the understanding of fragmentation processes in hadrontherapy and radioprotection in space with the FOOT experiment”, in Physica Scripta, doi: 10.1088/1402-4896/ac186b (2021)
- M. Toppi et al., “Elemental fragmentation cross sections for a ^{16}O beam of 400 MeV/u kinetic energy interacting with a graphite target using the FOOT ΔE -TOF detectors”, in Frontiers in Physics, doi: 10.3389/fphy.2022.979229 (2022)
- G. Silvestre et al., “Characterization of 150 μm thick silicon microstrip prototype for the FOOT experiment”, Journal of Instrumentation, doi: 10.1088/1748-0221/17/12/P12012 (2022)
- A. C. Kraan et al., “Calibration and performance assessment of the TOF-Wall detector of the FOOT experiment”, in Nuclear Instruments and Methods in Physics Research: Section A, doi: 10.1016/j.nima.2022.167615 (2023)
- L. Galli et al., “The fragmentation trigger of the FOOT experiment”, in Nuclear Instruments and Methods in Physics Research: Section A, doi: 10.1016/j.nima.2022.167757 (2023)
- C. Domingo-Pardo et al., “Advances and new ideas for neutron-capture astrophysics experiments at CERN n_TOF ”, European Physics Journal A, doi: 10.1140/epja/s10050-022-00876-7 (2023)
- N. Patronis et al., “Status report of the n_TOF facility after the 2nd CERN long shutdown period”, European Physics Journal Techniques and Instrumentation, doi: 10.1140/epjti/s40485-023-00100-w (2023)
- V. Alcayne et al., “A Segmented Total Energy Detector (sTED) optimized for (n,γ) cross-section measurements at n_TOF EAR2”, Radiation Physics and Chemistry, doi: 10.1016/j.radphyschem.2024.111525 (2024)
- G. Galati et al., “Charge identification of fragments produced in ^{16}O beam interactions at 200 MeV/n and 400 MeV/n on C and C_2H_4 targets”, in Frontiers in Physics, doi: 10.3389/fphy.2023.1327202 (2024)

Conference proceedings

- R. Zarrella, “Calibration and performances of the full scale ΔE -TOF prototype of the FOOT experiment”, in Il Nuovo Cimento C - Colloquia and Communications in Physics, doi: 10.1393/ncc/i2021-21017-6 (2021)

R. Zarrella, “*Nuclear fragmentation cross section measurements with the FOOT experiment*”, in EPJ Web Of Conferences, doi: 10.1051/epjconf/202328410001 (2023)

R. Zarrella, “*Characterization of the FOOT neutron detectors for nuclear fragmentation measurements at the n_TOF facility*”, Accepted for publication in Journal of Instrumentation (2024)

Co-author of other 8 conference proceedings

Other

R. Zarrella, “*Charge identification of nuclear fragments with the Time-Of-Flight detectors of the FOOT experiment*”, Master thesis, A.A. 2018-2019.

R. Zarrella, A. Manna et al., “*Characterization of the FOOT neutron detectors for nuclear fragmentation measurements at the n_TOF facility*”, Letter Of Intent, CERN-INTC-2022-020, INTC-I-242 (2022)

N. Patronis et al., “*The CERN n_TOF NEAR station for astrophysics and application-related neutron activation measurements*”, arXiv preprint, doi: <https://doi.org/10.48550/arXiv.2209.04443> (2022)