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YUNSHENG DONG

curriculum vitae

PERSONAL INFORMATION

First name and family name: Yunsheng Dong
Date of birth: 08/04/1989

QUALIFICATIONS

Current and previous positons

- 03/04/2023-ongoing: Post doctoral fellow (senior "fascia 3"), *Experimental physics*, Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Italy
- 01/04/2021-31/04/2023: Post doctoral fellow (junior "fascia 1"), *Measurements of nuclear fragmentation cross sections with the FOOT experiment for applications in medical physics and radioprotection in space*, Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Italy

Education

- 2021: Ph.D. in Physics Astrophysics and Applied Physics, *excellence*, "Nuclear fragmentation cross sections measurements for hadrontherapy: implementation and optimization of a beam monitoring system", supervised by Prof. Franco Camera and Giuseppe Battistoni at Università degli studi di Milano
- 2017: Master's degree in Physics, 110 *cum laude*, "Study and design of a drift chamber in the FOOT experiment", supervised by Prof. Franco Camera and Giuseppe Battistoni at Università degli studi di Milano.

Attended schools

- Seminario nazionale rivelatori innovativi, INFN, Torino (Italy), 9-13 October 2023
- FLASH radiotherapy: radiobiologia, prospettive cliniche, aspetti tecnologici e dosimetrici, Scuola superiore di fisica in medicina Piero Caldirola, Pisa (Italy), 29-30 September 2022
- Machine Learning applied to Nuclear Physics, experiment and theory, ECT* Talent school, Fondazione Bruno Kessler, online, 19-30 July 2021
- Mediterranean Machine Learning school, AI Education Foundation, online, 11-16 January 2021
- CERN Main school of computing, CERN, Cluj-Napoca (Romania) 15-28 September 2019
- XXVIII Giornate studio sui rivelatori, Scuola F.Bonaudi, Cogne (Italy) 11-15 February 2019
- Photosensors and Signal Processing in Particle Detectors, PRISMA detector lab, Mainz (Germany), 12-16 March 2018
- Summer School on PET-aided hadron therapy, MEDICIS-Promed, Fondazione CNAO (Pavia, Italy), 4-9 June 2017

Member of approved projects and experiments

- 2017-ongoing: **FOOT** (FragmentatiOn Of Target)
  - Deputy software coordinator (since 2023), working on the development, optimization and maintenance of the FOOT reconstruction software
  - Responsible of the drift chamber detector adopted in both the FOOT experimental setups
  - Member of the analysis team, working both on MC and experimental data analysis of the whole FOOT electronic spectrometer setup
- 2017-ongoing: **INSIDE** (INnovative Solution for In-beam Dosimetry in hadronthErapy)
  I'm a member of the Dose Profiler detector team. I contributed to the detector characterization and in the clinical trial data acquisition and data analysis tasks
- 2021-2023: **FRIDA** (Flash Radiotherapy with hIgh Dose-rate particle beAms research)
  I'm a member of the WP4 (FLASH treatment planning) team and I worked on the optimization of a treatment planning system suitable for the FLASH radiotherapy
- 2019-2022: **PAPRICA** (PAir PRoduction Imaging ChAmber)
  I worked to develop a track reconstruction algorithm suitable for the experimental requirements and I contributed in the detector design by analyzing Monte Carlo simulations
- 2017-2019: **MONDO** (MOnitor for Neutron Dose in hadrOntherapy)
  I worked on the detector MC simulation analysis

Collaborations with particle accelerator facilities

- **GSI** - Helmholtzzentrum fur Schwerionenforschung of Darmstadt, Darmstadt (Germany).
  Collaboration for the FOOT data takings conducted with both the experimental setups to measure the nuclear fragmentation cross sections of particles at the energy of interest of space radioprotection and hadrontherapy.
- **APSS** - Trento Proton Therapy Center, Trento (Italy).
  Collaboration activities with the proton beam facility for the characterization and performance assessment of the FOOT experiment drift chamber.
- **CNAO** - Centro Nazionale di Adroterapia Oncologica, Pavia (Italy).
  I worked for the low intensity beam characterization of the accelerator in the framework of the INSIDE project. At present, I'm collaborating for the clinical trial with patients of the INSIDE project and for the FOOT experiment data taking.

Review activities

- 2024-ongoing: Peer review of articles on *Nuclear Instruments and Methods in Physics Research - section A (NIM-A)*

Teaching activities

- AA 2022/2023 and AA 2023/2024: Teacher for the "Introduction to health and medical physics" course at Università degli studi di Milano, 16 hours per year
- AA 2023/2024: Tutor for the "Optics,electronics and modern physics laboratory" course at Università degli studi di Milano, specializing in the electronics module, 33 hours per year
- AA 2017/2018 - AA 2022/2023: Tutor for the "Optics,electronics and modern physics laboratory" course at Università degli studi di Milano, specializing in the electronics module, 50 hours per year

Thesis supervisor

- M.L. Ilisco, "Nanoparticelle, dosimetri a gel di Fricke e protonterapia: studio Monte Carlo all'interno del progetto NANOGedy", Bachelor degree, 26 October 2023
- S. Gatti, "Algoritmi di selezione e riconoscimento tracce nell'esperimento FOOT: identificazione degli eventi di fondo", Bachelor degree, 24 October 2023
- L. Lampertico, "Inter-fractional monitoring of 12C ions treatments with the Dose Profiler detector: simulation studies and clinical trial results at the CNAO facility", Master degree, 21 September 2023
- C. Radice, "Il ruolo del dose rate nell'effetto FLASH", Bachelor degree, 12 June 2023
- R. Gandini, "Nanoparticelle, matrici idrogeliche e dosimetri a gel di Fricke: studio Monte Carlo all'interno del progetto NANOGedy", Bachelor degree, 18 April 2023
- M. Oprandi, "Study and performance evaluation of the FOOT experiment track reconstruction algorithm", Bachelor degree, 18 April 2023

Physics divulgation projects

- 2022-ongoing: **Lab2Go**
  Lab2Go is an INFN and Sapienza University "Terza missine" project created to improve or realize physics laboratory activities in high schools. The researchers involved in the project are in charge to classify and, if possible, to repair the materials already present in the high school physics labs. They also have to prepare physics experiments suitable for the high school students, assisting the school personnel. I have been involved in the project since 2022, being the responsible for the "liceo scientifico Piero Bottoni" in A.A. 2022/2023 and "liceo scientifico Donatelli-Pascal" in A.A. 2023/2024.

RESEARCH ACTIVITY

My main research activity is inserted in the framework of nuclear physics with applications in medicine and space radiation protection. The principal project in which I work is the FOOT (FragmentatiOn Of Target) experiment, that aims to perform nuclear fragmentation cross section measurements of ^{4}He, ^{12}C and ^{16}O beams on thin C, C_2H_4 and PMMA targets, in the energy range 200-800 MeV/n. In addition, I work in different projects for the study and development of techniques and detectors optimized for applications in hadrontherapy.

The FOOT experiment

the FOOT (FragmentatiOn Of Target) project is a nuclear physics experiment approved in 2017 and founded by INFN. The main goal of the project is to measure the double differential cross sections ($d^2\sigma/d\Omega \cdot dE$) of fragments produced in nuclear interactions relevant for particle therapy and space radiation protection [2]. In order to reach the goal, FOOT is composed of two different setups for the detection of heavy ($Z \geq 3$) and light ($Z \leq 3$) fragments: the former are detected by an electronic spectrometer composed of different electronic sub detectors [15, 1], while the latter are measured by a separated detector using nuclear emulsions (emulsion cloud chamber) combined with a beam monitoring system [14].
I contributed to the design, optimization, construction and first operation of the FOOT experiment. My main work is focused on the beam monitoring system adopted in both the experimental setups and on the analysis of the Monte Carlo (MC) simulations and the experimental data of the FOOT electronic spectrometer. I'm the person in charge of a drift chamber adopted to measure the incoming beam direction and position, dealing both with the hardware settings and with the data acquisition and data analysis software of the detector. I developed the drift chamber track reconstruction algorithm and I'm the responsible of the detector representation, reconstruction and analysis codes within the FOOT software framework, being a core member of the software development team. I worked with the FLUKA MC tool to perform simulations and to estimate the detector performances. I optimized the gas choice and the electric field working point of the drift chamber by means of the GARFIELD++ MC tool. I collaborated with

the Roma1 and the Trento colleagues of the experiment to fix the hardware settings and the data acquisition code, participating in the first drift chamber test performed with cosmic rays and proton beams. I conducted the calibration and performance assessment of the drift chamber performed at the TIFPA (Trento, Italy) hadrontherapy center. In this occasion, I realized a dedicated data acquisition system to combine different detectors (scintillators, drift chamber and microstrip silicon detectors) adopted for the data taking. Then, I worked on the data analysis task, calibrating the space-time relations and measuring the efficiency and the spatial resolution of the drift chamber, comparing the experimental results with the MC simulations outcomes [3]. In addition, I realized and tested a space-time relations calibration algorithm that uses only the drift chamber data. I participated in all the FOOT data acquisitions performed with both the experimental setups. During the emulsion setup data takings conducted at the GSI synchrotron center (Darmstradt, Germany), I worked on all the aspects related to the beam monitoring system, adapting the acquisition and reconstruction codes to provide a fast response requested during the experiment [9][8].
In addition to all the tasks related to the drift chamber, I'm involved also in the FOOT electronic setup global track reconstruction and analysis team. I participated in a preliminary cross sections measurement experiment conducted at the CNAO (Pavia, Italy) hadrontherapy center with a different dedicated setup of detectors. The goal was to measure the differential cross sections (dσ/dE) of the production of light fragments at large angles in the $^{12}C + X$ reaction in the hadrontherapy energy range (100-350 MeV/u). In this occasion, I contributed in the data analysis performed to estimate the cross sections values [12]. A new paper on the measurements with a complete analysis that includes new angles and a comparison of data and MC predictions is in preparation. I was present in the first FOOT electronic setup data takings at GSI. In that occasion I worked with the drift chamber tracks to select the events and to measure the elemental fragmentation cross sections of ^{16}O beam at 400 MeV/u on a graphite target [18]. An updated version of the measurements with new data collected at GSI is in preparation.
At present, I'm continuing the collaboration in the FOOT experiment. In addition to the FOOT beam monitoring system hardware and software tasks, I'm working on the electronic setup global track reconstruction algorithm and I'm developing the analysis code adopted to provide the particle mass identification and the final differential cross section measurements. Since 2023, I'm the deputy software coordinator of the FOOT collaboration, working in the development, optimization and maintenance of the experiment simulation, reconstruction and analysis software codes.

The INSIDE project

I'm involved in the INSIDE (INnovative Solution for In-beam Dosimetry in hadronthErapy) project at CNAO. This project developed a charged particle tracking detector and a PET (Positron Emission Tomography) scanner able to perform an in vivo range verification during both carbon ion and proton treatments. In this experiment, I participated in the test and the performance assessment of the Dose Profiler detector, which is composed of layers of scintillating fibers and it is developed for the reconstruction of light fragments produced by the incident carbon ions. At present, I'm actively participating in the clinical trial of the INSIDE project conducted with the patients at CNAO (ID: NCT03662373) started in 2019 to evaluate the capability to detect the inter-fractional morphological changes [22, 4, 19, 5, 13, 11].

Concluded projects

FRIDA (Flash Radiotherapy with hIgh Dose-rate particle beAms research):
The FRIDA experiment has been developed to investigate the FLASH effect, which is a new ultrahigh dose-rates ($\geq$40 Gy/s) radiotherapy technique. The FRIDA project addresses several challenges posed by this potential revolution trying to provide a mechanistic description of the FLASH effect, to develop new acceleration approaches to enable the FLASH technology at the level of clinical implementation, to monitor proton and electron beams, to realize dosimeters suitable for the FLASH dose rates and to plan FLASH treatments of tumor cases with protons and electrons. The FRIDA experiment has been approved by INFN in 2021 and, in this framework, I'm involved in MC simulation and treatment planning tasks. I worked to introduce the parameters of interest of the FLASH effect within the Monte Carlo simulation tools and to develop and optimize a treatment planning system suitable for the FLASH radiotherapy [17, 16, 6].

PAPRICA (PAir PRoduction Imaging ChAmber):
This project is inserted in the particle therapy range monitoring framework. It aims to demonstrate the possibility of a new approach in the detection of the photons from nuclear de-excitation emitted during the particle therapy treatments by exploiting the pair production interactions. I was fully involved in the project and I contributed to the development of the reconstruction software and the detector performance assessment analysis. I worked with the MC simulations performed by means of FLUKA and the results showed the capability of the detector to measure the beam range with a spatial resolution of ~ 3 mm, compatible with the clinical requirements [20]. In addition, I studied the possibility to use the apparatus to perform a 3D inter-fractional monitoring in a real clinical case scenario, exploiting the data collected during the INSIDE project clinical trial. A new paper on this study is in preparation.

MONDO (MOnitor for Neutron Dose in hadrOntherapy)
The MONDO project has been developed to detect the fast secondary neutrons produced during hadrontherapy treatments. This device exploits the double elastic scattering interactions to measure the direction and the energy of neutrons by means of plastic scintillator targets. The MONDO prototype has already been constructed, tested and characterized [21, 10]. I worked in the collaboration in view of a future development of the FOOT experiment to perform measurements on neutrons cross sections.

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PUBLICATIONS

[1] Kraan. A.C. et al. “Charge identification of nuclear fragments with the FOOT Time-Of-Flight system”. In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 1001 (2021), p. 165206. ISSN: 0168-9002. DOI: 10.1016/j.nima.2021.165206.

[2] 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* 8 (2021), p. 555. ISSN: 2296-424X. DOI: 10.3389/fphy.2020.568242.

[3] **Dong, Y.** et al. “The Drift Chamber detector of the FOOT experiment: Performance analysis and external calibration”. In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 986 (2021). ISSN: 0168-9002. DOI: 10.1016/j.nima.2020.164756.

[4] E. Fiorina et al. “Detection of Interfractional Morphological Changes in Proton Therapy: A Simulation and In Vivo Study With the INSIDE In-Beam PET”. In: *Frontiers in Physics* 8 (2021), p. 660. ISSN: 2296-424X. DOI: 10.3389/fphy.2020.578388.

[5] M. Fischetti et al. “Interfractional monitoring of ^{12}C ions treatments: results from a clinical trial at the CNAO facility”. In: *Nature: Scientific Reports* 10 (2020). DOI: 10.1038/s41598-020-77843-z.

[6] G. Franciosini et al. “Preliminary study on the correlation between accelerated current and dose in water for an electron based linac”. In: *Frontiers in Physics* 12 (2024). DOI: 10.3389/fphy.2024.1249393.

[7] Silvestre G. et al. “Characterization of 150 μm thick silicon microstrip prototype for the FOOT experiment”. In: *Journal of Instrumentation* 17.12 (Dec. 2022), P12012. DOI: 10.1088/1748-0221/17/12/P12012.

[8] G. Galati et al. “Charge identification of fragments produced in 16O beam interactions at 200 MeV/n and 400 MeV/n on C and C2H4 targets”. In: *Frontiers in Oncology* 11 (2023). DOI: 10.3389/fphy.2023.1327202.

[9] G. Galati et al. “Charge identification of fragments with the emulsion spectrometer of the FOOT experiment”. In: *Open Physics* 19.1 (2021), pp. 383–394. DOI: 10.1515/phys-2021-0032.

[10] V. Giacometti et al. “Characterisation of the MONDO detector response to neutrons by means of a FLUKA Monte Carlo simulation”. In: *Radiation Measurements* 119 (2018), pp. 144–149. ISSN: 1350-4487. DOI: 10.1016/j.radmeas.2018.10.006.

[11] A.C. Kraan et al. “Localization of anatomical changes in patients during proton therapy with in-beam PET monitoring: A voxel-based morphometry approach exploiting Monte Carlo simulations”. In: *Medical Physics* 49.1 (2022), pp. 23–40. DOI: 10.1002/mp.15336.

[12] I. Mattei et al. “Measurement of 12C Fragmentation Cross Sections on C, O, and H in the Energy Range of Interest for Particle Therapy Applications”. In: *IEEE Transactions on Radiation and Plasma Medical Sciences* 4.2 (2020), pp. 269–282. DOI: 10.1109/TRPMS.2020.2972197.

[13] M. Moglioni et al. “In-vivo range verification analysis with in-beam PET data for patients treated with proton therapy at CNAO”. In: *Frontiers in Oncology* 12 (2022). DOI: 10.3389/fonc.2022.929949.

[14] M.C. Montesi et al. “Ion charge separation with new generation of nuclear emulsion films”. In: *Open Physics* 17.1 (2019), pp. 233–240. DOI: 10.1515/phys-2019-0024.

[15] M. Morrocchi et al. “Development and characterization of a ΔE-TOF detector prototype for the FOOT experiment”. In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 916 (2019), pp. 116–124. ISSN: 0168-9002. DOI: 10.1016/j.nima.2018.09.086.

[16] A. Muscato et al. “Treatment planning of intracranial lesions with VHEE: comparing conventional and FLASH irradiation potential with state-of-the-art photon and proton radiotherapy”. In: *Frontiers in Physics* (2023). DOI: 10.3389/fphy.2023.1185598.

[17] A. Sarti et al. “Deep Seated Tumour Treatments With Electrons of High Energy Delivered at FLASH Rates: The Example of Prostate Cancer”. In: *Frontiers in Oncology* 11 (2021). DOI: 10.3389/fonc.2021.777852.

[18] M. Toppi et al. “Elemental fragmentation cross sections for a 16O beam of 400MeV/u kinetic energy interacting with a graphite target using the FOOT ΔE-TOF detectors”. In: *Frontiers in Physics* 10 (2022). DOI: 10.3389/fphy.2022.979229.

[19] M. Toppi et al. “Monitoring Carbon Ion Beams Transverse Position Detecting Charged Secondary Fragments: Results From Patient Treatment Performed at CNAO”. In: *Frontiers in Oncology* 11 (2021), p. 2028. ISSN: 2234-943X. DOI: 10.3389/fonc.2021.601784.

[20] M. Toppi et al. “PAPRICA: The Pair Production Imaging Chamber—Proof of Principle”. In: *Frontiers in Physics* 9 (2021), p. 47. ISSN: 2296-424X. DOI: 10.3389/fphy.2021.568139.

[21] M. Toppi et al. “The MONDO Tracker: Characterisation and Study of Secondary Ultrafast Neutrons Production in Carbon Ion Radiotherapy”. In: *Frontiers in Physics* 8 (2020), p. 524. DOI: 10.3389/fphy.2020.567990.

[22] G. Traini et al. “Review and performance of the Dose Profiler, a particle therapy treatments online monitor”. In: *Physica Medica* 65 (2019), pp. 84–93. ISSN: 1120-1797. DOI: 10.1016/j.ejmp.2019.07.010.

CONFERENCES

Oral talks

- Sesto Incontro Nazionale di Fisica Nucleare (INFN2024), "Nuclear fragmentation cross sections measurements: the FOOT experiment", Trento (Italy), 26-28 February 2024
- VIth Topical workshop on modern aspects in nuclear structure, "Measurement of the cross section for light fragment production at large angle in the ^{12}C collision on C, O and H in 100-350 MeV/u energy range", Bormio (Italy), 6-11 February 2023
- IEEE Nuclear Science Symposium, "Nuclear fragmentation cross sections measurements for hadrontherapy and space radioprotection: the FOOT experiment", Milan (Italy), 5-12 November 2022
- Applied Nuclear Physics Conference (ANPC), "The PAir PRoduction Imaging ChAmber (PAPRICA)", Prague (Czech Republic), 13-15

September 2021
- Workshop Società per le Ricerche sulle Radiazioni (SIRR), "Nuclear fragmentation cross sections measurements for hadrontherapy: the FOOT experiment", Napoli (Italy), 10 September 2021
- First workshop "Trento Proton Beam Line Facility", "Calibration of the drift chamber within the FOOT experiment", Online, 09 November 2020
- 106th National Congress of the Italian physical Society (SIF), "Calibration and performance assessment of the drift chamber adopted in the FOOT experiment", Online, 14-18 September 2020, **Proceeding:** Il nuovo cimento 44C, 2021, 43, doi:10.1393/ncc/i2021-21043-4
- 104th National Congress of the Italian physical Society (SIF), "Study of the performance of the FOOT experiment", Cosenza (Italy), 17-21 September 2018
- XI International conference on Nuclear Structure Properties (NSP2018), "Study of the performance of the FOOT experiment", Trabzon (Turkey), 11-14 September 2018, **Proceeding:** ALKU Journal of Science (NSP2018 special issue).

Posters

- Analysis of the alpha clustering phenomena in the fragmentation of 12C and 16O ions at 200 and 400 MeV/u in the FOOT experiment, "60th International winter meeting on nuclear physics", Bormio, 22-26 January 2024
- FLASH radiotherapy and particle therapy conference (FRPT), "Nuclear fragmentation cross sections measurements for hadrontherapy: the FOOT experiment", Barcelona (Spain), 30 November-2 December 2022
- XIX Convegno nazionale della Società per le Ricerche sulle Radiazioni (SIRR), "External calibration and performance assessment of the drift chamber detector adopted in the FOOT experiment", Online, 10-12 November 2020
- International Conference Medical Accelerators and Particle Therapy, "Beam and target fragmentation in hadrontherapy: The FOOT experiment", Seville (Spain), 4-6 September 2019

Date: 15/03/2024
Place: Milano (Italy)