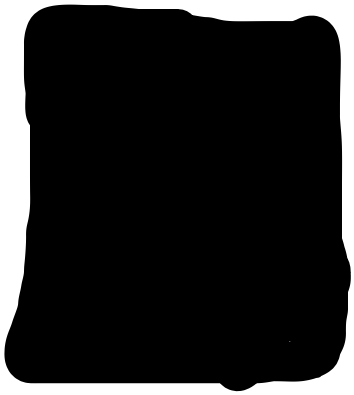
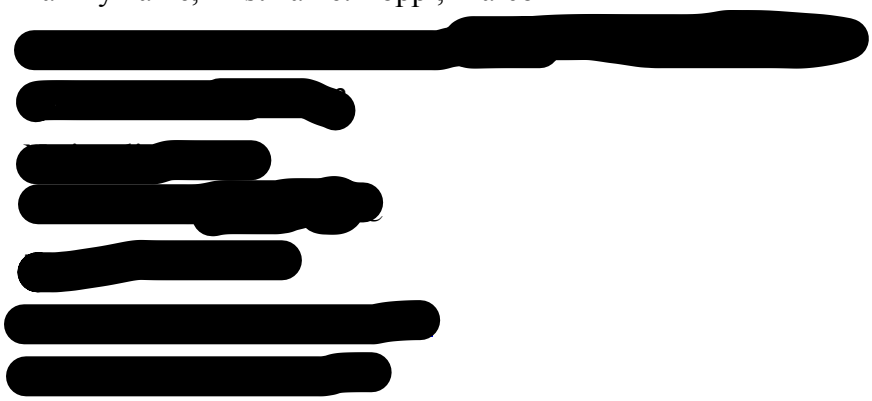
Curriculum vitae Marco Toppi



PERSONAL INFORMATION

Family name, First name: Toppi, Marco



- **CURRENT AND PREVIOUS POSITIONs**

01/2020 – Researcher (RTD A)

Measurement Techniques for Light Ions Nuclear Reactions and study of their application in Particle Therapy

(Settore concorsuale 02/A1 Fisica sperimentale delle interazioni fondamentali - Settore scientifico- disciplinare FIS/01 Fisica sperimentale)

Dipartimento di Scienze di Base a Applicate per l'Ingegneria (SBAI)

Sapienza Università di Roma - Italy

03/2016 – 2019 Post.Doc

Development of integrated technologies for monolithic pixel trackers, aimed at upgrading the ALICE Inner Tracking System and for nuclear fragmentation experiments for applications in Particle Therapy

Laboratori Nazionali di Frascati (LNF)

Istituto Nazionale di Fisica Nucleare (INFN) - Italy

11/2014 – 2016 Post.Doc

Nuclear Techniques applied to Medical Physics

Istituto Nazionale di Fisica Nucleare (INFN) at Dipartimento di Scienze di Base a Applicate per l'Ingegneria (SBAI) - Italy

- **EDUCATION**

11/2011–6/2015 PhD - Excellence
Fragmentation measurements with the FIRST experiment
Physics Tor Vergata University, Rome - Italy
PhD Supervisors: Prof. Annalisa D'Angelo, Prof. Vincenzo Patera

2008 – 2011 Master Degree - 110/110 cum laude.
Study of the electric discharge in gases by analyzing waveforms induced in RPC with gaps of various sizes
Physics Tor Vergata University, Rome - Italy
Master Supervisor: Prof.Rinaldo Santonico, Dr. Barbara Liberti

- **SCIENTIFIC RESPONSIBILITIES and COORDINATION ACTIVITIES**

2021 – 2023 **FlashDC** (Flash Dosimeter Counter) - "Progetti di Gruppi di Ricerca 2020" of Regione Lazio (150 keuros). Responsible for the WP1: Detector development of a dosimeter for FLASH radiotherapy.

2021 – **Deputy Software Coordinator** of the FOOT collaboration for the fragments reconstruction and identification in the FOOT apparatus

2020 - 2022 **3DIT**: 3D plastIc scintillaTor - University calls for research, SAPIENZA University, (10keuro), I work at the characterisation of 3D printed samples of organic-metallic scintillator for low cost, high rate SPECT imaging.

2019 – **Low intensity Beam Monitor** for the CNAO (Centro Nazionale di Adroterapia Oncologica) Experimental Room. Coordinator of the construction, development, and characterisation of a low intensity beam monitor for the CNAO experimental room.

2019 – 2021 **PAPRICA** (Pair PRoduction Imaging ChAmber) - INFN CSN5 national project (75keuros). Local Coordinator for the experiment at LNF: coordination of the building of a range monitor device for proton therapy treatment.

2017 – 2019 **Inner Tracking System** (ITS) of ALICE experiment. Local Responsible at LNF of the tests of the detector read-out chain during the production and pre-production phases.

● TEACHING ACTIVITIES AND SUPERVISION OF STUDENTS

2020 – **Professor** of the course of General Physics 2 (Electromagnetism and Optics) for the Degree course of "Ingegneria Civile e Industriale" and "Ingegneria dell'Informazione, Informatica e Statistica" - Sapienza Università di Roma - Italy

2014 – 2016 **Assistant** of the course of General Physics 2 (Electromagnetism and Optics) for the Degree course of Mechanical Engineering - Sapienza Università di Roma - Italy

2020 – **Co-Supervisor** of 1 Ph.D Students
SBAI Department - Sapienza Università di Roma – Italy

2018 – **Co-Supervisor** of 4 Master Students
Physics Department - Sapienza Università di Roma – Italy

● EDITORING and REVIEWING ACTIVITIES

2020 – Reviewer of International Scientific Journal: Journal of Instrumentation JINST

2016 – 2019 Referee as Institute Review Committee for ALICE collaboration

● PUBLIC COMPETITIONS

- Winner of the public competition of ENEA 01/2017 for a permanent position as researcher for *"the study and the development of techniques of measurements of the natural and artificial radioactivity and of dosimetry of ionizing particles"* (https://www.opportunita.enea.it/component/jdownloads/?task=download.send&id=240&catid=74&Itemid=101). After winning I gave up that position for the current one.
- Present in the final ranking of the INFN Call 20012/2018 for the professional profile of III professional level Researcher with permanent employment contract, for research activities in the field of experimental physics of fundamental interactions.
- Present in the final rankings of the CREF Calls 21 and 20 (2016) for the professional profile of III professional level Researcher with permanent employment contract, for research

activities in experimental research activities within the research themes of the CREF.

- **MEMBERSHIPS OF SCIENTIFIC SOCIETIES**

2019 – Member of the FOOT collaboration [https://web.infn.it/foot/en/home/]

2016 – Associate Member of CERN as member of the ALICE collaboration in LNF

2016 – Member of the ALICE collaboration [https://home.cern/science/experiments/alice]

2011 – 2016 Member of the FIRST collaboration (FIRST – Fragmentation of Ions Relevant for Space and Therapy)

- **EXPLOITATION, COMUNICATION AND DISSEMINATION**

Activities performed at the Laboratori Nazionali di Frascati (LNF) for:

- 2011, 2012, 2013, 2017: Full academic years: guided visits program for high school students
- 27.9.2013 Organization of the dissemination event of *Notte dei Ricercatori*
- 11-12.6.2012 Organization of the High School Student Summer
- 10-12.10.2012 Organization of the High-School Teacher Seminars: Workshop with scintillators

Member of the organizing committee of the ALICE Physics Week 2018 at the LNF laboratories

- **RESEARCH ACTIVITIES**

My research focuses on the field of **Nuclear Physics** and on the application of nuclear and particle physics to the field of Particle Therapy and Space Radioprotection. The bulk of my research activity, since my PhD, was focused on the study of the nuclear fragmentation and in the development of new detectors.

The research activity in the ALICE collaboration gave me the opportunity to strengthen my knowledge in nuclear physics, in the data analysis, and in bleeding edge hardware technique, as the development of pixel silicon detectors (MAPS - Monolithic Active Pixel Sensors).

For the total number of publications, I can quote

- **h-index of 24** with more than 176 publications in refereed international journals for a total

of more than 2149 citations (http://www.scopus.com) (conference proceeding excluded);

- **4** publication as first author and **2** publication as corresponding author

Research Activity

My research career has taken place in the field of **Nuclear Physics**.

In fundamental Nuclear Physics I participate to large collaboration as ALICE and to medium collaboration as FIRST and FOOT experiments. In applied physics, in Particle-Radio Therapy (PRT) field, I focused my study on the nuclear fragmentation measurement of light ions. This offered me the opportunity to investigate new detectors with growing independence in leading projects and activities.
During my career I worked both on data analysis (for fragmentation cross section measurements and for measurement of light flavour hadrons production with ALICE apparatus) and in detectors development. I made my experience in a national and international collaboration environment focused on R&D activities, facing both hardware and software challenges related to such applications.

I started my PhD research work in the **FIRST international collaboration** (Fragmentation of Ions Relevant for Space and Therapy), which aimed to measure the double differential cross sections (in angle and energy) of ^{12}C ions nuclear fragmentation process occurring in thin targets at energies **of interests both in the field of particle therapy and in the field of radiation protection in space**. I led the analysis of charged fragments emitted at a small angle. I carried out the calibration of the vertex (silicon pixel - MAPS) and ToF (plastic scintillator) detectors, I have developed both the local detectors reconstruction and the global tracking algorithms and, finally, I took care of the measurement of the differential cross sections as a function of the angle and the kinetic energy of the emitted fragments. The analysis has been published in Physical Review C [10], with me as first author, and I presented it at international conferences [h, i, l].

After my PhD I continued my work with a research fellow, joining the ARPGroup (Applied Radiation Physics Group) at SBAI Department (Rome, Italy), to work on nuclear fragmentation measurements at the energies of interest for PRT applications. In this context my activity was divided among three different and complementary objectives:

- Performing the *measurement of double differential target fragmentation cross sections* induced in the patient tissue by protons of energies of interest in PRT applications. Target fragmentation, currently poorly known, has to be modelled and implemented in the TPS (Treatment Planning System) for a PRT treatment used to optimize dose delivery inside the patient in therapeutic sessions. To perform such measurements, I joined the **FOOT (FragmentatiOn Of Target)** collaboration and within FOOT I developed the charge identification and tracking algorithms and proceeded in their validation through MC simulations, I have carried out the detectors calibration [11]-[13], [20], the background study, and I'm taking care of the first cross sections measurements of the FOOT collaboration for the measurement of 16O beam at 400 MeV/n impinging on a C target related to a preliminary data acquisition performed at GSI in 2019 [3] whose preliminary results have been shown in (a).
- Performing the *measurement of the secondary particle emission induced by a primary hadrontherapy beam*, with the aim of designing an **online monitor** capable of measuring the beam range inside a patient [8,9], [15]-[19]. I started developing **tracking detectors** working on a scintillating fibre device - the *Dose Profiler* - for the detection of charged secondary particles emitted during ^{12}C ions treatments. The DoseProfiler was designed to be used as an on-line monitor and has been installed at the CNAO (National Center of Oncological Hadrontherapy) center (Pavia, Italy). I took care, during the design phase, of the tests with scintillating fibres of different thicknesses and of the development of the final readout. *The Dose Profiler is now used within a* ***clinical trial*** *at CNAO with 20 enrolled patients and the first results* ***ever obtained of an on-line monitoring of ^{12}C ions treatments*** *have been published in [5].* I've also shown how the same detector can be used during a carbon ion treatment to monitor the beam transverse position detecting charged secondary fragments [1]. The Dose profiler works in dual mode with a PET scanner used for the monitoring of the range of the beam during proton irradiation, exploiting the beta+ emitter nuclei produced in the nuclear interactions between the beam and the patient [30].

  Beside my interest in charged particles detection, I also participated in the development of an innovative neutron tracker dedicated to the measurements of neutron cross section production in the energy range of particle physics, MONDO (MOnitor for Neutron Dose in hadrOntherapy). I've studied the detector expected performances and the preliminary results obtained so far have been published in [4].
- I finally work on the development of a detector for an innovative technique of radioguided surgery with beta electrons and on the study of the feasibility of such technique for a variety of "nuclear medicine" radionuclides [21], [22].

In 2016 I moved to "Laboratori Nazionali di Frascati" (LNF) of INFN ("Istituto Nazionale di Fisica Nucleare", Italy), working on the upgrade of the **ALICE experiment**, i.e. to its Inner Tracking System (ITS) for the Run 3 of the LHC. The ITS consists of layers of Monolithic Active Pixel Sensors (MAPS) ALPIDE (ALice PIxel DEtector) detectors for which I contributed to the development, pre-production and production phase. This work has been of fundamental importance in my scientific growth, since I had to deal with many assembly's critical issues (50-100 μm MAPS silicon sensors), the development of the acquisition software, the test of the assembled detectors and their quality assurance before their final shipping and assembly at CERN. I was the local production responsible for the detector test and readout in LNF.

In the same period, I've also taken care of the analysis of the measurement of the transverse momentum spectra of light flavour hadrons (pions, kaons and protons) produced in different colliding systems pp, p-Pb, Pb-Pb and Xe-Xe at different energies in the LHC, within the Light Flavour Physics Working Group of ALICE, of interest for the understanding of the properties of the Quark-Gluon Plasma (QGP) [23]-[29]. Two papers in which I gave a significant contribution in the analysis of the data acquired with the TOF (Time-Of-Flight) detector of ALICE producing TOF standalone transverse momentum spectra for pions, kaons and protons have been published in [6] and [7].

My work of analysis and detector development in ALICE is documented in different invited and attended conferences and seminars where I presented my results [b, c, d, e, f, g].

The experience in the ALICE collaboration have been fundamental to strengthen my knowledge in the detection techniques of nuclear and particle physics. In 2018 I had the chance to put in use the know-how I gained on tracking MAPS detectors in the Particle Therapy field supporting a young national grant (PAPRICA, PAir PRoduction Imaging ChAmber), devoted to the detection of prompt photons emitted in PT treatments, to monitor the range of the beam in the patient. Within PAPRICA, I am in charge of the LNF group coordination and I am responsible for the **tracking detector** construction using ALPIDE sensors. The detector expected performances have been studied through a MC simulation and have been published in [2].

In 2020 I joined again the ARPG collaboration working as professor at SBAI department (Sapienza). In a joint effort between the chemistry, engineering and physics department of SBAI, with the aim of developing **innovative plastic scintillators with very high timing capabilities** that could be used within 3D printers (Sapienza Ateneo Funding, 3DIT project).

This experience strengthened my interest in detector developments as well as the quality of my skills in the field. The time detectors are of crucial importance in the FOOT experiment as the Time of Flight of the particles is exploited to identify the nuclear fragments.
Since 2020 I devote my activities in the FOOT experiment mainly to the trigger definition and in the cross-section data analysis, results presented in [a]. In July 2021 I participated to the FOOT data taking at GSI (Oxygen 200 and 400 MeV/u on different target material) being the **trigger strategy** responsible. I'm also the new **deputy coordinator** of the FOOT reconstruction software.

The know-how I gained in the development of detectors for the monitoring of charged and neutral radiations in the applied physics field has been recognised within the ARPG collaboration and, in 2020, **I was asked to lead the development, construction, test and integration of a low intensity beam monitor** (BM) for the CNAO experimental room. CNAO requested a detector capable of being directly interfaced with the Dose Delivery System and the research team's control room. In addition, it should provide the primary ^{12}C ions counting and beam position whenever the beam intensity falls below 1 MHz, that is the current lower limit of operation of CNAO standard beam monitors. I already designed a monitor prototype using scintillating fibres with a custom SiPM readout that is matching the CNAO requirements. The full detector construction is now ongoing and its installation is expected in late 2021.

The work performed in all these different research areas was the ground base on which a new idea for a beam monitoring for Flash Radiation Therapy exploiting electrons and protons has been developed. The stimulating environment (international collaborations, the lively academic exchange of ideas with other students and researchers, ...), the variety of detection techniques and applications that I witnessed, gave me the confidence in exploring the FLASH therapy field [14] and proposing the solution of the monitoring problem in FLASH applications. In 2021 we submit and obtained a funding ("Progetti di Gruppi di Ricerca 2020" of Regione Lazio) for the FlashDC project, of which I am WP1 coordinator.

My experience with detectors is also completed by my master degree thesis about studying and improving the performances of single and multi-gaps RPCs detectors. A part of the work of my thesis has been published in [Aielli G. et al. JINST 2016 doi: 10.1088/1748-0221/11/07/P07014].

Scientific products

Selection of 30 publications:

1. **M.Toppi** et al., "Monitoring carbon ion beams transverse position detecting charged secondary fragments: results from patient treatment performed at CNAO", Front. Oncol. doi: 10.3389/fonc.2021.601784.
2. **M.Toppi** et al., *"PAPRICA: The Pair Production Imaging Chamber-Proof of Principle"*. Front. Phys. 9 (2021) 568139. doi: 10.3389/fphy.2021.568139.
3. G.Battistoni et al. (**M.Toppi corresponding author**), *"Measuring the Impact of Nuclear Interaction in Particle Therapy and in Radio Protection in Space: the FOOT Experiment"* Frontiers in Physics 8 (2021) 568242 doi: 10.3389/fphy.2020.568242.
4. **M.Toppi** et al., *"The MONDO Tracker: Characterisation and Study of Secondary Ultrafast Neutrons Production in Carbon Ion Radiotherapy"* Frontiers in Physics 8 (2020) 567990 doi: 10.3389/fphy.2020.567990.
5. M. Fischetti et al. (**M.Toppi corresponding author**), *"Inter-fractional monitoring of 12C ions treatments: results from a clinical trial at the CNAO facility"* Scientific Reports 10 (1) (2020) 20735 doi: 10.1038/s41598-020-77843-z.
6. S. Acharya et al. (ALICE collaboration), "Production of charged pions, kaons, and (anti-) protons in Pb-Pb and inelastic pp collisions at sNN =5.02 TeV", Physical Review C, 2020, 101, 4, doi: 10.1103/PHYSREVC.101.044907
7. S. Acharya et al. (ALICE collaboration), "Multiplicity dependence of light-flavor hadron production in pp collisions at s =7 TeV", Physical Review C, 2019, 99, 2, doi: 10.1103/PhysRevC.99.024906
8. M. Rovituso et al., *"Fragmentation of 120 and 200 MeV/u He-4 ions in water and PMMA targets"*, PHYSICS IN MEDICINE AND BIOLOGY 62 (2017) 4 1310-1326 doi: 10.1088/1361-6560/aa5302.
9. M. Marafini et al., *"Secondary radiation measurements for particle therapy applications: nuclear fragmentation produced by He-4 ion beams in a PMMA target"*, PHYSICS IN MEDICINE AND BIOLOGY 62 (2017) 4 1291-1309 doi: 10.1088/1361-6560/aa5307.

10. **M. Toppi** et al. (FIRST Collaboration), *"Measurement of fragmentation cross sections of 12C ions on a thin gold target with the FIRST apparatus"*, Phys. Rev. C 93 (2016) 064601, doi: 10.1103/PhysRevC.93.064601.

11. Kraan A.C. et al, Charge identification of nuclear fragments with the FOOT Time-Of-Flight system, NIM A Volume 100111 June 2021 Article number 165206. Doi: 10.1016/j.nima.2021.165206

12. Dong Yunsheng et al., The Drift Chamber detector of the FOOT experiment: Performance analysis and external calibration, NIM A 986 (2021) 164756. Doi: https://doi.org/10.1016/j.nima.2020.164756

13. S Colombi et al., Enhancing the understanding of fragmentation processes in hadrontherapy and radioprotection in space with the FOOT experiment. Phys. Scr. 96 () 114013. https://doi.org/10.1088/1402-4896/ac186b

14. Sarti, A. et al., Deep Seated Tumour Treatments With Electrons of High Energy Delivered at FLASH Rates: The Example of Prostate Cancer, *Frontiers in Oncology*, Volume 1123 December 2021. Doi: 10.3389/fonc.2021.777852

15. Mattei, I. et al., "Measurement of charged particle yields from PMMA irradiated by a 220 MeV/u C-12 beam", PHYSICS IN MEDICINE AND BIOLOGY, Volume: 62 Issue: 21 Pages:8483-8494, pub- lished: nov 7 2017. doi: 10.1088/1361-6560/aa8b35.

16. S. Muraro et al., "Monitoring of Hadrontherapy Treatments by Means of Charged Particle Detection", FRONTIERS IN ONCOL- OGY, Volume: 6, Published: AUG 3 2016. doi:10.3389/fonc.2016.00177.

17. A.Rucinski et al., "Secondary radiation measurements for particle therapy applications: charged particles produced by 4He and 12C ion beams in a PMMA target at large angle", 2018, Phys. Med. Biol. 63 055018, doi:10.1088/1361-6560/aaa36a.

18. I.Mattei et al., "Secondary radiation measurements for particle therapy applications: prompt photons produced by 4He, 12C and 16O ion beams in a PMMA target", 2017, Phys. Med. Biol. 62 1438. doi:10.1088/1361-6560/62/4/1438.

19. G.Traini et al., "Design of a new tracking device for on-line beam range monitor in carbon therapy", 2017, Physica Medica 34 1827, doi:10.1016/j.ejmp.2017.01.004.

20. Mattei, I. et al.,*"Measurement of 12C Fragmentation Cross Sections on C, O, and H in the Energy Range of Interest for Particle Therapy Applications",* IEEE Transactions on Radiation and Plasma Medical Sciences 4 (2020) 2 269-282 doi:10.1109/TRPMS.2020.2972197

21. C. Mancini-Terracciano et al., Feasibility of beta-particle radioguided surgery for a variety of "nuclear medicine" radionuclides, Physica Medica 43 (2017) 127–133, http://dx.doi.org/10.1016/j.ejmp.2017.10.012

22. E. Solfaroli Camillocci et al., First ex vivo validation of a radioguided surgery technique with beta-radiation, Physica Medica 32 (2016) 1139–1144, http://dx.doi.org/10.1016/j.ejmp.2016.08.018

23. Acharya S et al., Transverse momentum spectra and nuclear modification factors of charged particles in pp, p-Pb and Pb-Pb collisions at the LHC. *JHEP* Volume 2018, Issue 111 November 2018 Article number 13. 10.1007/JHEP11(2018)013

24. Acharya S et al, Centrality and pseudorapidity dependence of the charged-particle multiplicity density in Xe–Xe collisions at s_{NN}=5.44TeV. *Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics* Volume 790, Pages 35 – 4810. 10.1016/j.physletb.2018.12.048

25. Acharya S et al., Transverse momentum spectra and nuclear modification factors of charged particles in Xe–Xe collisions at s_{NN}=5.44TeV. *Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics* Volume 788, Pages 166 – 179. 10.1016/j.physletb.2018.10.052

26. Acharya S. et al., Charged-particle production as a function of multiplicity and transverse spherocity in pp collisions at √s=5.02 and 13 TeV. *European Physical Journal C* Volume 79, Issue 101 October 2019 Article number 857. 10.1140/epjc/s10052-019-7350-y

27. Acharya S. et al., Multiplicity dependence of (multi-)strange hadron production in proton-proton collisions at √s = 13 TeV. *European Physical Journal C* Volume 80, Issue 21 February 2020 Article number 167. 10.1140/epjc/s10052-020-7673-8

28. Acharya S. et al., Multiplicity dependence of π , K, and p production in pp collisions at √s=13 TeV. *European Physical Journal C* Volume 80, Issue 81 August 2020 Article number 693. 10.1140/epjc/s10052-020-8125-1

29. Acharya S. et al., Charged-particle pseudorapidity density at mid-rapidity in p–Pb collisions at √sNN = 8.16 TeV. *European Physical Journal C* Volume 79, Issue 41 April 2019 Article number 307. 10.1140/epjc/s10052-019-6801-9

30. Fiorina E. et al., Detection of Interfractional Morphological Changes in Proton Therapy: A Simulation and In Vivo Study With the INSIDE In-Beam PET, Frontiers in Physics January 2021, Volume 8, Article 578388, doi:10.3389/fphy.2020.578388

Seminar and Conferences

(a) PANIC 2021, Online, 5-10/09/2021, *"Measurements of 16O fragmentation cross sections on C target with the FOOT apparatus"*.

(b) ICNFP 2019, Creta, 21-29/08/2019, "*Multiplicity and energy dependence of light charged particle production in ALICE at the LHC"*.

(c) Sapienza University of Rome 2019, **Invited** Seminar, *"Silicon Pixel detector technologies for basic and applied research applications, from CERN to PT experiments"*.

(d) TIFPA 2018, **Invited** Seminar, *"The ALICE Inner Tracking System upgrade"*.

(e) First International DMEG Workshop 2019, Salerno, 10-11/7/2019, **Invited** talk *"Spectra Measurements with MRPC based Time Of Flight system in ALICE"*

(f) SIF 2019, L'Aquila, 23-27/9/2019 "*The upgrade of the ALICE Inner Tracking System"*

(g) INFN-LNF, 11/12/2019, **Invited** Seminar: *"Multiplicity and energy dependence of light charged particle production in ALICE at the LHC"*

(h) 54th International Winter Meeting on Nuclear Physics, Bormio, 25-29/01/2016, *"Measurements of 12C ions fragmentation cross sections on a thin gold target with the FIRST apparatus"*. Proceeding: PoS(BORMIO2016)035.

(i) 12th International Conference on Nucleus-Nucleus Collisions, Catania, 21-26/06/2015, *"Measurement of secondary particle production induced by particle therapy ion beams impinging on a PMMA target"*. Proceeding doi:10.1051/epjconf/201611705007 EPJ Web Conf. 117, 05007.

(l) NUBA Conference Series: Nuclear Physics and Astrophysics, Antalya, Turkey, 15-2/09/2014, *"Measurements of 12C ion fragmentation on thin carbon target from the*

FIRST collaboration at GSI" Proceeding in doi:10.1088/1742-6596/590/1/012035 J. Phys. Conf. Ser. 590, 1, 012035.

Quanto dichiarato in queste pagine corrisponde a verità, ai sensi degli articoli 46 e 47 del D.P.R. 445 del 2000

Autorizzo il trattamento dei miei dati personali ai sensi del Decreto Legislativo 30 giugno 2003, n. 196 "Codice in materia di protezione dei dati personali".

DATA, 25/01/2022

FIRMA