Matteo Salomoni

Experimental High Energy Physics · Applied physics and Medical applications

Viale Sarca 324C, Milano, Italy.

(+39) 3486952734 | matteo.salomoni@cern.ch | matteo.salomoni@unimib.it | msalomon | Matteo Salomoni

Current Position

Fellow *Geneva, Switzerland*

CERN *August 2020 - July 2023*

Working on LHCb ECAL Upgrade Ib and Upgrade II on Geant4 simulations, readout optimization, module design and assembly, DAQ for test beam activities and data analysis.

Previous positions and Education

Post-doctoral researcher *Milano, Italia*

University of Milano Bicocca (UniMiB) *April 2019 - March 2021*

Primary investigator and coordinator of the **ATTRACT-EU** project Photoquant
"Nano-photonics applied to ultrafast single photon quantum sensors"

Project associate (during the post-doc in UniMiB) *Geneva, Switzerland*

CERN *August 2019–July 2020*

Project coordinator within the EP-CMX group: R&D for future HEP light detectors in the frame of the RD18.

Ph.D. in Physics and Astronomy *Milano, Italy*

University of Milano-Bicocca/CERN *October 2015–February 2019*

Worked on Calorimetry, Photonic crystals applied to Medical Applications and Gamma Spectroscopy, Nano-crystals and Meta-materials. Thesis title: "How to boost scintillation-based detection". Ph.D. in Physics and Astronomy

Master of Science (M.Sc.) *Milano, Italy*

University of Milano-Bicocca *2013–2015*

Worked on Nano-crystals. Thesis title: "Study of nanocrystals and photonic crystals applied to medical devices". Master degree in Applied Physics.

Bachelor's degree *Bologna, Italy*

University of Bologna *2008-2012*

Astronomy

Ph.D. experience

Calorimetry

TICAL project (ERC Advanced Grant 338953) and ULTIMA project (ERC Proof of Concept #680552): "4D total absorption Time Imaging CALorimeter.": This project proposed a novel approach in particle detectors by developing a highly granular calorimeter with high-resolution timing information. The key point was to introduce light production, collection and detection techniques that are becoming accessible due to technological advancements in this field. I specifically worked on simulating (Geant4 and CAMFR) and producing Photonic Crystal Structures for light extraction gain using a scintillator [1, 2], as well as studying and optimizing crystal fibers.

Photonic crystals - Medical applications

TurboPET (EUROSTAR project, ID #8974): "New high-resolution, high-sensitivity dedicated breast positron emission tomography scanner.": The project developed a next-generation nuclear imaging breast Positron Emission Tomography (PET) systems with high sensitivity and high resolution based on the integration of cutting-edge photonic and nano-structuration techniques. Specifically, photonic crystals were applied to the surface of the inorganic scintillators with the purpose to increase the extraction efficiency of the scintillation photons. My role was to develop test benches for measuring crystals and photonic crystals properties, such as light yield, decay time, and angular distribution of the extracted photons. A simulation framework was also developed ad-hoc for this project, merging the two tools: Geant4 (particle physics simulator) and CAMFR (CAvity Modeling FRamework, photonic simulations) [3, 4].

Photonic crystals - Gamma spectroscopy

US-funded DNDO project (#HSHQDC-13-C-B0040):" Photonic Crystal Structures for Transformational Gain in Scintillator Performance.": This project focused on the research and development of gamma radiation detectors with enhanced energy resolution. Nano-imprinted UV-cured photonic crystal were optimized to increase the extraction efficiency of scintillating light for several crystals, such as LYSO, GYGAGG, and SrI2 [5]. I performed extensive studies on simulation optimization, performance testing of the imprinted sample, and proof of concept studies related to innovative diffraction gratings.

Nano-crystals and metamaterials

Ultrafast light from nanometric scintillators: Two classes of innovative materials were investigated to generate ultrafast scintillation light in response to ionization: two-dimensional CdSe nanoplatelets (NPLs) and spherical CdSe/CdS core/giant shell quantum dots (GS QDs). We demonstrate that the emission rates of these NCs under pulsed X-ray excitation can be as fast as 77 ps [6] (effective decay time) thanks to multiexcitonic emission. Other than the chemical production of the materials, I contributed to every part of this work.

Post-doctoral experience

Calorimetry for HL-LHC

RD18 activity within the Crystal clear collaboration (CERN): I contributed to the research and development to inorganic scintillation materials for novel ionizing radiation detectors, for high-energy physics, medical imaging, and industrial applications. Using Geant4 simulations and scintillation characterization, I studied and optimized the effect of including a fast, low density material in a well-known inorganic scintillator, to boost the emission rise and decay time of such a hybrid configuration (meta-material) and finally develop new scintillators suitable for crystal electromagnetic calorimeters (homogeneous or sampling) of HL-LHC experiments.

Innovative ionizing radiation detectors

R&D on innovative bulk and nano-material to detect ionizing radiation (continuation of the Ph.D. work):: I worked on the characterization and data analysis of new ionizing radiation detectors for various collaborations, in the forms of bulk materials [7], composite materials [8], and meta-materials [9].

Innovative Light detectors

Photoquant (ATTRACT-EU project, UniMiB (see project webpage) - Nano-photonics applied to ultrafast photon sensors: as a project coordinator and primary investigator, I am the initiator of this exploratory R&D and responsible for the quality of the research produced. The project aims at exploiting the potential of the emerging field of nano-photonics for developing a new generation of highly efficient and ultrafast photons sensors. The project proposes two different approaches: the first will exploit the ability of nano-structures to concentrate light into subwavelength volumes, designing an interface layer between the light source and the silicon photo-multiplier (SiPM) to guide all the photons to an individual single photon avalanche diode (SPAD). This will allow solving the problem of efficiency losses due to the SPAD fill-factor in standard SiPM readout configurations. The second will be to optimize a design of hyperbolic metamaterial photoconversion region in the SiPM structure, to improve the quantum efficiency and reduce the time jitter through a precise localization of the photoconversion process in the SiPM. This innovative device could have close to 100% photo-detection efficiency, ultra-high cell density, negligible correlated noise and beyond state-of-the-art primary noise. This project resulted in the publication of the following paper [10].

CERN fellowship

LHCb ECAL Upgrade II R&D

Optical simulation, assembly, and testing of the new ECAL modules: during this fellowship I started performing Geant4 simulations to understand the performance of several technologies of possible new ECAL modules, that will be used to substitute the current LHCb ECAL Shashlik technology during Upgrade Ib and II due to radiation damage [11, 12]. The simulations included different versions of SPACAL-type calorimeter modules, with different absorber types (Pb, W), different active materials (organic and inorganic scintillators) with various surface finishes and claddings, different optical coupling and light collection techniques (fiber bundle, light guides, direct contact) and different light readout (R12421, R7600U-20, R14755U-100, R11187, R7899). I designed, planned, and assembled 2 of the modules and build part of the setup used to test them: an experimental box with remotely controlled 2-axes motors for angular alignment and angular scans, remotely controllable attenuators and LED calibration system for the PMTs, graphical user interface (GUI) for remote control (Python). I designed and 3D printed the holders needed to assemble the modules and the readout (PMTs, light guides, and LED calibration system). I worked on the data acquisition (DAQ) of the test beam setup for the implementation of a synchronous triggering scheme between different DAQs and I also worked on the analysis of the test beam data, specifically on the time resolution and light collection efficiency. I also contributed in the design and assembly of the 20 voltage dividers used for the current ECAL prototypes. Several peer-reviewed papers have been released since the start of my participation to the LHCb community [13–32] [33–51] [52–56].

Multidisciplinary networks participation

Member of The Crystal Clear Collaboration: *since 2015*

An international collaboration which is active on the research and development of inorganic scintillation materials for novel ionizing radiation detectors, for high-energy physics, medical imaging, and industrial applications.

Member of H2020 Ascimat H2020-TWINN: *2016 - 2018*

This collaboration was created to boost scientific excellence and technology-transfer capacity in advanced scintillating materials. Thanks to this network, a strong connection with the FZU (Institute of Physics of the Czech Academy of Sciences) was created, for the development of new scintillating materials for future detectors (including HEP). We currently provide testing facilities and expertise in order to characterize their newly produced crystals.

Member of COST Fast Advanced Scintillator Timing (TD1401): *2014 - 2018*

This EU action aimed at establishing a multidisciplinary network that brings together European experts from academia and industry to ultimately achieve scintillator-based detectors with timing precision of better than 100ps.

Technical skills

Instrumentation

Scintillators: deep knowledge of inorganic and organic scintillators, as thin films or bulk in several form factors. Expert user of some commercial instrumentation: Spectrometer (2300i from PrincetonInstruments), Streak camera (Hamamatsu), Spectrofluorimeter (PerkinElmer), Spectrophotometer (PerkinElmer), Transmission and Reflection measurements (PerkinElmer), together with several custom-made benches for light yield, rise time (60 ps impulse response function), and decay time measurements.
Photo-detectors: expertise with the following devices: MCPs (custom-made Novisibirsk 1" device, Hamamatsu), PMTs (Hamamatsu, Katod), SiPMs (Hamamatsu, Ketek, Broadcom, FBK), Hybrid PMT (Becker&Hickl), CCD (ORCA digital CCD camera, Hamamatsu), photodiodes and photoresistors in general.
Read-out electronics and signal treatment: deep understanding of Digitizers (CAEN V1742, DT5720A), TDCs (MOD. V1290 VME controlled through V2718 or xTDC4 from Cronologic, PCIe controlled), Oscilloscopes, ADC (e.g. VME Model 1182 controlled through V2718), DRS4 chip from PSI (evaluation board, chip included also in CAEN V1742), attenuators (keysight 8495 remotely controlled through an Arduino), signal shapers and amplifiers (e.g. Ortec 4723).
Sources and light collection: expert user of lasers (Horiba, Alphalas, PicoQuant), pulsed X-ray tube (Hamamatsu), optical fibers, photonic fibers, and light guides.
Standard characterization techniques from material science:: user of optical and electron microscopy, Profilometry.
Nano-fabrication: user of Atomic Layer deposition, Electron beam lithography, Focus Ion beam.
3D printing : expert user of a Prusa i3 MK3S+, remotely controlled via Octoprint + Raspberry pi.

Programming Languages:

Proficient user of: C++, Python, Matlab, Arduino (C), Bash, Perl, Fortran90, LaTeX.

Software toolkits

Particle physics simulators: expertise in Geant4 and MCNPX.
Data analysis: user of Root, Python, and Matlab.
Photonic simulations: user of the CAvity Modeling FRamework (CAMFR), basic use of COMSOL.
Mechanical drawing and design: user of CatiaV5, AutoCAD Inventor, and Prusa Slicer for 3D printing.
Test beam facilities: frequent user of both DESY and SPS facilities in different beam-line and configurations.
Others: general know-how in the use of microcontroller and in mechatronics, 3D printing (Prusa i3 MK3S+), laser cutting.

Teaching and 3rd mission

CERN Idea^2 mentor *Geneva, Switzerland*

Laser cutter expert *2021, Present*

Expert and reference in the use of laser cutting machine for non-metallic material.

Tutor *University of Milano Bicocca*

Tutoring Physics 1 laboratory *40 hours, Sep. 2016 - Oct. 2017*

Physics laboratory tutoring in the first year of bachelor in physics, University of Milano-Bicocca.

Tutor *University of Milano Bicocca*

Tutoring Physics 1 laboratory *40 hours, Sep. 2019 - Oct. 2020*

Physics laboratory tutoring remotely (COVID-19 time) in the first year of bachelor in physics, University of Milano-Bicocca.

Supervisor *CERN/University of Milano Bicocca*

Supervising master student. *Sep. 2010 - Oct. 2011*

Supervising master's students from RWTH Aachen University and the University of Milano Bicocca.

Presentations at International Conferences

Talk	**SCINT2017**: Conference on Scintillating materials and their Applications, Chamonix, 18 - 22 September 2017. Talk title: "Photonic crystals slabs applied to inorganic scintillators [2]".
Invited Talk	**MEDAMI**: VI Mediterranean Thematic Workshop in Advanced Molecular Imaging: IMAGING IN IMMUNOTHERAPY, Valencia, 15 - 17 May 2019. Talk title: "Using heterostructures and photonic crystal to reach 10 ps timing resolution with a scintillator-based detector".
Invited Talk	**SCINT2019**: Conference on Scintillating materials and their Application, Sendai, 30 Nov - 4 Oct 2019. Talk title: "Integrating Fast-Emitting Materials with State-of-the-Art Scintillators as a Pathway to New Performance".
Talk	**SPW2019**: Single-Photon Workshop, Milano, 21-25 Oct 2019. Talk title: "Future perspective of SiPM technology".
Poster	**IPRD**: Topical Seminar on Innovative Particle and Radiation Detectors , Siena, 3 - 6 October 2016. Poster title: "Enhancing Light Extraction Efficiency of Inorganic Scintillators".
Poster	**IEEE2019**: Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC), Manchester, 26 Oct - 2 Nov 2019. Poster title: "From SiPM efficiency to the future perspective of photo-detection".
Talk	**IEEE2019**: Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC), Manchester, 26 Oct - 2 Nov 2019. Talk title: "Integrating Fast-Emitting Materials with State-of-the-Art Scintillators as a Pathway to New Performance".
Talk	**TIPP**: Technology and Instrumentation in Particle Physics conference, Online, 24 May - 29 May 2020. Talk title: "The Upgrade II of the LHCb Calorimeter".

Presentations at Collaboration Meetings

Talk	**LHCb week**: Collaboration meeting, Online, 9 Dec 2020. Talk title: "Test-Beam Desy 2020: results".
Talk	**EP R&D days**: EP R&D CERN section meeting, Online, 11 Nov 2021. Talk title: "Status of Scintillator Based Calorimetry".
Talk	**EP R&D days**: EP R&D CERN section meeting, Geneva - CERN Globe, 20 Jun 2022. Talk title: "Status of Scintillator Based Calorimetry".

Trainings/Schools

Scint Summer School 2017: Conference on Scintillating Materials and their Applications. September 14-17

Introduction to EU R&D framework: Training on EU R&D framework programmes at the ASCIMAT winterschool 2016. September 14-17

32nd Course Nano-optics: Principles on Nano-optics enabling basic research and applications. Ettore Majorana Foundation and Center for Scientific Culture: Ïnternational school of Atomic and Molecular Spectroscopy¨2015, July 4-19.

Relevant publications with personal contribution

Bibliometric indices: 56 total publications with an H-index of 16.

Crystals, 2018

Enhancing Light Extraction of Inorganic Scintillators Using Photonic Crystals [1]:

Personal contribution: development of the Geant4 and CAMFR simulation code, used for photonic crystal design optimization of samples NI1, NI2, TurboPET presented in the review. For the same samples, I studied and planned the photonic crystal production, I developed the light yield experimental bench and performed data taking and data analysis with Python. Main author of the paper.

IEEE, 2018

Photonic crystal slabs applied to inorganic scintillators [2]:

Personal contribution: development of the Geant4 and CAMFR simulation code, used for photonic crystal design optimization. Study and planning of the photonic crystal production, development of the light yield experimental bench, data taking and data analysis with Python. Main author of the paper.

NIM-A, 2019

Improving light output and coincidence time resolution of scintillating crystals using nanoimprinted photonic crystal slabs [3]:

Personal contribution: development of the Geant4 and CAMFR simulation tool, used for photonic crystal design optimization.

IEEE NSS, 2016

Prototype construction and clinical tests improving PET images through photonic solutions [4]:

Personal contribution: development of the Geant4 and CAMFR simulation code, used for photonic crystal design optimization, development of the light yield experimental bench, data taking and data analysis with Python and ROOT.

IEEE, 2018

Enhanced scintillation light extraction using nanoimprinted photonic crystals [5]:

Personal contribution: simulation code development, study and planning of the photonic crystal production, photonic crystal design, development of the experimental test bench, data taking and data analysis.

IEEE, 2016

Ultrafast emission from colloidal nanocrystals under pulsed x-ray excitation [6]:

Personal contribution: development of the experimental test bench, data taking and data analysis with MATLAB.

NIM-A, 2021

Multipurpose Ce-doped Ba-Gd silica glass scintillator for radiation measurement [7]:

Personal contribution: Validation and formal analysis of the data obtained.

Nature Photonics, 2022

Composite fast scintillators based on high-Z fluorescent metal–organic framework nanocrystals [8]:

Personal contribution: performed light yield measurements, analysis and data interpretation.

Frontiers, 2022

A new method to characterize low stopping power and ultra-fast scintillators using pulsed x-rays [9]:

Personal contribution: contributed to the conception of the study and supervised it.

APL Photonics, 2020

CMOS-compatible all-dielectric metalens for improving pixel photodetector arrays [10]:

Personal contribution: conceived and planned the Photoquant project, supervised and coordinated the project and contributed to the writing of the paper.

NIM-A, 2023

Performance of a spaghetti calorimeter prototype with tungsten absorber and garnet crystal fibres [11]:

Personal contribution: test beam preparation and coordination, experimental setup, data analysis and interpretation.

CDS CERN, 2023

Framework TDR for the LHCb Upgrade II - Opportunities in flavour physics, and beyond, in the HL-LHC era [12]:

Personal contribution: SpaCal modules preparatory studies, module and readout assembly, readout electronics, remote control and DAQ, data analysis and interpretation.

References

[1] M. Salomoni, R. Pots, E. Auffray, P. Lecoq, Enhancing light extraction of inorganic scintillators using photonic crystals, Crystals 8 (2). doi:10.3390/cryst8020078.
URL https://www.mdpi.com/2073-4352/8/2/78

[2] M. Salomoni, R. Pots, P. Lecoq, E. Auffray, S. Gundacker, M. Paganoni, B. Singh, M. Marshall, V. V. Nagarkar, Photonic crystal slabs applied to inorganic scintillators, IEEE Transactions on Nuclear Science 65 (8) (2018) 2191–2195. doi:10.1109/TNS.2018.2817362.

[3] R. H. Pots, M. Salomoni, S. Gundacker, S. Zanettini, V. Gâté, E. Usureau, D. Turover, P. Lecoq, E. Auffray, Improving light output and coincidence time resolution of scintillating crystals using nanoimprinted photonic crystal slabs, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 940 (2019) 254–261. doi:https://doi.org/10.1016/j.nima.2019.06.026.
URL https://www.sciencedirect.com/science/article/pii/S0168900219308666

[4] S. Zanettini, V. Gâté, E. Usureau, J. Ruscica, F. Hamouda, K. Nomenyo, L. Cunff, K. Hind, G. Lerondel, M. Salomoni, R. Pots, E. Auffray, P. Lecoq, J. Alamo, J. Prior, A. Iltis, D. Turover, Photonic solutions nano-patterning of crystals turbo-crystals characterisation turbo-mammi prototype construction clinical tests improving pet images through photonic solutions: the turbo-pet project improved light extraction efficiency on 2 inches lyso with nanopatterned tio 2 photonic crystals (11 2016). doi:10.13140/RG.2.2.35793.63848.

[5] B. Singh, M. S. J. Marshall, S. Waterman, C. Pina-Hernandez, A. Koshelev, K. Munechika, A. Knapitsch, M. Salomoni, R. Pots, P. Lecoq, V. V. Nagarkar, Enhanced scintillation light extraction using nanoimprinted photonic crystals, IEEE Transactions on Nuclear Science 65 (4) (2018) 1059–1065. doi:10.1109/TNS.2018.2811646.

[6] R. Turtos, S. Gundacker, A. Polovitsyn, S. Christodoulou, M. Salomoni, E. Auffray, I. Moreels, P. Lecoq, J. Grim, Ultrafast emission from colloidal nanocrystals under pulsed x-ray excitation, Journal of Instrumentation 11 (10) (2016) P10015. doi:10.1088/1748-0221/11/10/P10015.
URL https://dx.doi.org/10.1088/1748-0221/11/10/P10015

[7] V. Dormenev, A. Amelina, E. Auffray, K.-T. Brinkmann, G. Dosovitskiy, F. Cova, A. Fedorov, S. Gundacker, D. Kazlou, M. Korjik, N. Kratochwil, V. Ladygin, V. Mechinsky, M. Moritz, S. Nargelas, R. Novotny, P. Orsich, M. Salomoni, Y. Talochka, G. Tamulaitis, A. Vaitkevicius, A. Vedda, H.-G. Zaunick, Multipurpose ce-doped ba-gd silica glass scintillator for radiation measurements, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 1015 (2021) 165762. doi:https://doi.org/10.1016/j.nima.2021.165762.
URL https://www.sciencedirect.com/science/article/pii/S0168900221007476

[8] J. Perego, I. Villa, A. Pedrini, E. C. Padovani, R. Crapanzano, A. Vedda, C. Dujardin, C. X. Bezuidenhout, S. Bracco, P. E. Sozzani, A. Comotti, L. Gironi, M. Beretta, M. Salomoni, N. Kratochwil, S. Gundacker, E. Auffray, F. Meinardi, A. Monguzzi, Composite fast scintillators based on high-z fluorescent metal–organic framework nanocrystals, Nature Photonics 15 (5) (2021) 393–400. arXiv:https://doi.org/10.1038/s41566-021-00769-z, doi:https://doi.org/10.1038/s41566-021-00769-z.
URL https://doi.org/10.1038/s41566-021-00769-z

[9] F. Pagano, N. Kratochwil, I. Frank, S. Gundacker, M. Paganoni, M. Pizzichemi, M. Salomoni, E. Auffray, A new method to characterize low stopping power and ultra-fast scintillators using pulsed x-rays, Frontiers in Physics 10. doi:10.3389/fphy.2022.1021787.
URL https://www.frontiersin.org/articles/10.3389/fphy.2022.1021787

[10] E. Mikheeva, J.-B. Claude, M. Salomoni, J. Wenger, J. Lumeau, R. Abdeddaim, A. Ficorella, A. Gola, G. Paternoster, M. Paganoni, E. Auffray, P. Lecoq, S. Enoch, Cmos-compatible all-dielectric metalens for improving pixel photodetector arrays, APL Photonics 5 (11) (2020) 116105.

arXiv:https://doi.org/10.1063/5.0022162, doi:10.1063/5.0022162.
URL https://doi.org/10.1063/5.0022162

[11] L. An, E. Auffray, F. Betti, F. Dall'Omo, D. Gascon, A. Golutvin, Y. Guz, S. Kholodenko, L. Martinazzoli, J. Mazorra De Cos, E. Picatoste, M. Pizzichemi, P. Roloff, M. Salomoni, D. Sanchez, A. Schopper, A. Semennikov, P. Shatalov, E. Shmanin, D. Strekalina, Y. Zhang, Performance of a spaghetti calorimeter prototype with tungsten absorber and garnet crystal fibres, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 1045 (2023) 167629. doi:https://doi.org/10.1016/j.nima.2022.167629.
URL https://www.sciencedirect.com/science/article/pii/S0168900222009214

[12] C. M. LHCb Collaboration, Framework TDR for the LHCb Upgrade II - Opportunities in flavour physics, and beyond, in the HL-LHC era, Tech. rep., CERN, Geneva (2021).
URL https://cds.cern.ch/record/2776420

[13] R. Aaij, et al., Measurement of prompt charged-particle production in pp collisions at $\sqrt{s} = 13$ TeV, JHEP 01 (2022) 166. arXiv:2107.10090, doi:10.1007/JHEP01(2022)166.

[14] R. Aaij, et al., Study of the doubly charmed tetraquark T_{cc}^+, Nature Commun. 13 (1) (2022) 3351. arXiv:2109.01056, doi:10.1038/s41467-022-30206-w.

[15] R. Aaij, et al., Measurement of the $B_s^0 \to \mu^+\mu^-$ decay properties and search for the $B^0 \to \mu^+\mu^-$ and $B_s^0 \to \mu^+\mu^-\gamma$ decays, Phys. Rev. D 105 (1) (2022) 012010. arXiv:2108.09283, doi:10.1103/PhysRevD.105.012010.

[16] R. Aaij, et al., Updated search for B_c^+ decays to two charm mesons, JHEP 12 (2021) 117. arXiv:2109.00488, doi:10.1007/JHEP12(2021)117.

[17] R. Aaij, et al., Study of coherent J/ψ production in lead-lead collisions at $\sqrt{s_{\rm NN}} = 5$ TeV, JHEP 07 (2022) 117. arXiv:2107.03223, doi:10.1007/JHEP07(2022)117.

[18] R. Aaij, et al., Measurement of the W boson mass, JHEP 01 (2022) 036. arXiv:2109.01113, doi:10.1007/JHEP01(2022)036.

[19] R. Aaij, et al., Measurement of the photon polarization in $\Lambda_b^0 \to \Lambda\,\gamma$ decays, Phys. Rev. D 105 (5) (2022) L051104. arXiv:2111.10194, doi:10.1103/PhysRevD.105.L051104.

[20] R. Aaij, et al., Evidence for a new structure in the $J/\psi p$ and $J/\psi\bar{p}$ systems in $B_s^0 \to J/\psi p\bar{p}$ decays, Phys. Rev. Lett. 128 (6) (2022) 062001. arXiv:2108.04720, doi:10.1103/PhysRevLett.128.062001.

[21] R. Aaij, et al., Simultaneous determination of CKM angle γ and charm mixing parameters, JHEP 12 (2021) 141. arXiv:2110.02350, doi:10.1007/JHEP12(2021)141.

[22] R. Aaij, et al., Identification of charm jets at LHCb, JINST 17 (02) (2022) P02028. arXiv:2112.08435, doi:10.1088/1748-0221/17/02/P02028.

[23] R. Aaij, et al., Search for the doubly charmed baryon $^+_{cc}$ in the $^+_c\pi^-\pi^+$ final state, JHEP 12 (2021) 107. arXiv:2109.07292, doi:10.1007/JHEP12(2021)107.

[24] R. Aaij, et al., Search for CP violation in $\Xi_b^- \to pK^-K^-$decays, Phys. Rev. D 104 (5) (2021) 052010. arXiv:2104.15074, doi:10.1103/PhysRevD.104.052010.

[25] R. Aaij, et al., Search for the radiative $\Xi_b^- \to \Xi^-\gamma$ decay, JHEP 01 (2022) 069. arXiv:2108.07678, doi:10.1007/JHEP01(2022)069.

[26] R. Aaij, et al., J/ψ photoproduction in Pb-Pb peripheral collisions at $\sqrt{s_{NN}}$= 5 TeV, Phys. Rev. C 105 (3) (2022) L032201. arXiv:2108.02681, doi:10.1103/PhysRevC.105.L032201.

[27] R. Aaij, et al., Observation of $\Lambda_b^0 \to D^+p\pi^-\pi^-$ and $\Lambda_b^0 \to D^{*+}p\pi^-\pi^-$ decays, JHEP 03 (2022) 153. arXiv:2112.02013, doi:10.1007/JHEP03(2022)153.

[28] R. Aaij, et al., Observation of the $B^0 \to \overline{D}^{*0} K^+\pi^-$ and $B_s^0 \to \overline{D}^{*0} K^-\pi^+$ decays, Phys. Rev. D 105 (7) (2022) 072005. arXiv:2112.11428, doi:10.1103/PhysRevD.105.072005.

[29] R. Aaij, et al., Tests of lepton universality using $B^0 \to K_S^0 \ell^+\ell^-$ and $B^+ \to K^{*+}\ell^+\ell^-$ decays, Phys. Rev. Lett. 128 (19) (2022) 191802. arXiv:2110.09501, doi:10.1103/PhysRevLett.128.191802.

[30] R. Aaij, et al., Constraints on the CKM angle γ from $B^\pm \to Dh^\pm$ decays using $D \to h^\pm h'^\mp \pi^0$ final states, JHEP 07 (2022) 099. arXiv:2112.10617, doi:10.1007/JHEP07(2022)099.

[31] R. Aaij, et al., Observation of the suppressed Λb0→DpK- decay with D→K+π- and measurement of its CP asymmetry, Phys. Rev. D 104 (11) (2021) 112008. arXiv:2109.02621, doi:10.1103/PhysRevD.104.112008.

[32] R. Aaij, et al., Observation of excited Ω_c^0 baryons in $\Omega_b^- \to \Xi_c^+ K^-\pi^-$decays, Phys. Rev. D 104 (9) (2021) L091102. arXiv:2107.03419, doi:10.1103/PhysRevD.104.L091102.

[33] R. Aaij, et al., Search for the doubly charmed baryon Ω_{cc}^+, Sci. China Phys. Mech. Astron. 64 (10) (2021) 101062. arXiv:2105.06841, doi:10.1007/s11433-021-1742-7.

[34] R. Aaij, et al., Angular analysis of $B^0 \to D^{*-} D_s^{*+}$ with $D_s^{*+} \to D_s^+\gamma$ decays, JHEP 06 (2021) 177. arXiv:2105.02596, doi:10.1007/JHEP06(2021)177.

[35] R. Aaij, et al., Observation of Two New Excited Ξ_b^0 States Decaying to $\Lambda_b^0 K^-\pi^+$, Phys. Rev. Lett. 128 (16) (2022) 162001. arXiv:2110.04497, doi:10.1103/PhysRevLett.128.162001.

[36] R. Aaij, et al., Study of Z Bosons Produced in Association with Charm in the Forward Region, Phys. Rev. Lett. 128 (8) (2022) 082001. arXiv:2109.08084, doi:10.1103/PhysRevLett.128.082001.

[37] R. Aaij, et al., Study of B_c^+ decays to charmonia and three light hadrons, JHEP 01 (2022) 065. arXiv:2111.03001, doi:10.1007/JHEP01(2022)065.

[38] R. Aaij, et al., Measurement of $\chi_{c1}(3872)$ production in proton-proton collisions at $\sqrt{s} = 8$ and 13 TeV, JHEP 01 (2022) 131. arXiv:2109.07360, doi:10.1007/JHEP01(2022)131.

[39] R. Aaij, et al., Test of lepton universality in beauty-quark decays, Nature Phys. 18 (3) (2022) 277–282. arXiv:2103.11769, doi:10.1038/s41567-021-01478-8.

[40] R. Aaij, et al., Measurement of the lifetimes of promptly produced Ω_c^0 and Ξ_c^0 baryons, Sci. Bull. 67 (5) (2022) 479–487. arXiv:2109.01334, doi:10.1016/j.scib.2021.11.022.

[41] R. Aaij, et al., Observation of an exotic narrow doubly charmed tetraquark, Nature Phys. 18 (7) (2022) 751–754. arXiv:2109.01038, doi:10.1038/s41567-022-01614-y.

[42] R. Aaij, et al., Measurement of the Nuclear Modification Factor and Prompt Charged Particle Production in $p-Pb$ and pp Collisions at $\sqrt{s_{NN}}$=5 TeV, Phys. Rev. Lett. 128 (14) (2022) 142004. arXiv:2108.13115, doi:10.1103/PhysRevLett.128.142004.

[43] R. Aaij, et al., Angular analysis of the rare decay $B_s^0 \to \phi\mu^+\mu^-$, JHEP 11 (2021) 043. arXiv:2107.13428, doi:10.1007/JHEP11(2021)043.

[44] R. Aaij, et al., Observation of a $\Lambda_b^0 - \overline{\Lambda}_b^0$ production asymmetry in proton-proton collisions at $\sqrt{s} = 7$ and 8 TeV, JHEP 10 (2021) 060. arXiv:2107.09593, doi:10.1007/JHEP10(2021)060.

[45] R. Aaij, et al., Observation of the Mass Difference Between Neutral Charm-Meson Eigenstates, Phys. Rev. Lett. 127 (11) (2021) 111801. arXiv:2106.03744, doi:10.1103/PhysRevLett.127.111801.

[46] R. Aaij, et al., Centrality determination in heavy-ion collisions with the LHCb detector, JINST 17 (05) (2022) P05009. arXiv:2111.01607, doi:10.1088/1748-0221/17/05/P05009.

[47] R. Aaij, et al., Angular Analysis of $D^0 \to \pi^+\pi^-\mu^+\mu^-$ and $D^0 \to K^+K^-\mu^+\mu^-$ Decays and Search for CP Violation, Phys. Rev. Lett. 128 (22) (2022) 221801. arXiv:2111.03327, doi:10.1103/PhysRevLett.128.221801.

[48] R. Aaij, et al., Branching Fraction Measurements of the Rare $B_s^0 \to \phi\mu^+\mu^-$ and $B_s^0 \to f_2'(1525)\mu^+\mu^-$- Decays, Phys. Rev. Lett. 127 (15) (2021) 151801. arXiv:2105.14007, doi:10.1103/PhysRevLett.127.151801.

[49] R. Aaij, et al., Measurement of the charm mixing parameter $y_{CP}-y_{CP}^{K\pi}$ using two-body D^0 meson decays, Phys. Rev. D 105 (9) (2022) 092013. arXiv:2202.09106, doi:10.1103/PhysRevD.105.092013.

[50] R. Aaij, et al., Study of charmonium and charmonium-like contributions in $B^+ \to J/\psi\eta K^+$ decays, JHEP 04 (2022) 046. arXiv:2202.04045, doi:10.1007/JHEP04(2022)046.

[51] R. Aaij, et al., Observation of the doubly charmed baryon decay $\Xi_{cc}^{++} \to \Xi_c'^+\pi^+$, JHEP 05 (2022) 038. arXiv:2202.05648, doi:10.1007/JHEP05(2022)038.

[52] R. Aaij, et al., Search for the decay $B^0 \to \phi\mu^+\mu^-$, JHEP 05 (2022) 067. arXiv:2201.10167, doi:10.1007/JHEP05(2022)067.

[53] R. Aaij, et al., Test of lepton flavour universality using $B^0 \to D^{*-}\tau^+\nu_\tau$ decays with hadronic τ channelsarXiv:2305.01463.

[54] R. Aaij, et al., Study of charmonium decays to $K_S^0K\pi$ in the $B \to (K_S^0K\pi)K$ channelsarXiv:2304.14891.

[55] R. Aaij, et al., Precision measurement of CP violation in the penguin-mediated decay $B_s^0 \to \phi\phi$arXiv:2304.06198.

[56] R. Aaij, et al., Search for $D^*(2007)^0 \to \mu^+\mu^-$ in $B^- \to \pi^-\mu^+\mu^-$ decaysarXiv:2304.01981.