Federico **De Guio**

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Professional History

- Since 2019 — **Post-doctoral Researcher** (RTDB) at *Università degli Studi di Milano–Bicocca*.
- 2016 - 2019 — **Post-doctoral Research Associate** at *Texas Tech University*.
- 2013 - 2016 — **Fellow at *CERN*** (Marie-Curie EU COFUND), Geneva.
- 2012 - 2013 — **Post-doctoral contract** at the *Università degli Studi di Milano–Bicocca*.
- 2010 - 2011 — ***INFN* Fellow at *CERN***, Geneva.
- 2008 — **Stage** at the *Quantum sensors and grid computing lab*.

Education

Jan 2012 — **Ph.D. in particle physics** with *Università degli Studi di Milano–Bicocca*.
Thesis title — "Search for a heavy gauge boson W′ in the final state with electron and E_T^{miss}".
Supervisor — prof. Tommaso Tabarelli de Fatis (*Università degli Studi di Milano–Bicocca*)

Feb 2008 — **Master of Science degree in Physics.**
Thesis title — "Search for the Higgs boson in the $A/H \to \tau^+\tau^- \to e\mu$ decay channel with the CMS detector at the LHC".
Supervisor — prof. Tommaso Tabarelli de Fatis (*Università degli Studi di Milano–Bicocca*)
prof. Sandra Malvezzi (*INFN*)

Oct 2005 — **Bachelor of Science degree in Physics.**
Thesis title — "Mechanical quenching of streamers in resistive plate chambers".
Supervisor — prof. Tommaso Tabarelli de Fatis (*Università degli Studi di Milano–Bicocca*)

Scientific Coordination and Organization

- Since 2019 — **Member of the HCAL Award Committee** for the CMS experiment.
- 2019 — **Co-coordinator** of the Electronics Simulation Group for the High Granularity Calorimeter of CMS (10+ physicists).
  Responsible of implementing the electronics signal description for the HGCAL in the CMS simulation framework.
- Since 2018 — **Referee** for the Journal of Instrumentation (JINST).
- Since 2016 — **Shift Leader** for the CMS experiment.
- Since 2016 — **Member of the analysis review committee** for multiple CMS publications.
- 2017 - 2018 — **Co-coordinator** of the Detector Performance Group for the hadronic calorimeter of CMS (50+ physicists).
  Responsible of coordinating the detector calibration effort, the commissioning and the performance optimization of trigger system, energy reconstruction, detector simulation and data quality.
- 2013 - 2016 — **Co-coordinator** of the Data Quality Monitoring and Data Certification group at CMS (50+ physicists and computer scientists).
  Responsible of coordinating the activity of the data quality monitoring and data certification team and responsible of setting the monitoring strategy of CMS for Run 2.

2012 - 2013 **Co-coordinator** of the Prompt Feedback Group for the electromagnetic calorimeter or CMS (10+ physicists).
Provide support to the data taking activities with fast offline analyses to ensure good data quality.

Awards, Qualifications and Indicators

Dec 2015 **CMS 2015 Achievement Award** for "His vital role in managing the CMS Data Quality Monitoring infrastructure".
Awarded by the CMS Collaboration Board.

Jan 2014 ***Abilitazione Scientifica Nazionale*: qualified** (*Professore di II fascia*).

Publications **1078** (direct link to inspirehep here).

H-Index **161.**

Supervision and teaching

Since 2009 **Supervising student activity.**
Since the beginning of my PhD, I enjoyed working closely with students over-seeing their contribution to the CMS experiment:

- supervisor of six bachelor and master students from the University of Milan working on different topics related to the study and the optimization of the performance of the CMS electromagnetic calorimeter and to aspects of the $H \to \gamma\gamma$ analysis;
- supervisor of five CERN summer student working on the introduction of machine learning techniques in the data quality monitoring system of CMS;
- supervisor of one PhD student (Tyler Wang) working on di-jet resonance searches at CMS;
- supervisor of one PhD student (Tielige Mengke) working on the inter-calibration of the hadronic calorimeter of CMS.

2020 - 2021 **Teacher of the course *Preparazione di Esperienze Didattiche*** – School of Mathematics, *Università degli Studi di Milano–Bicocca*.
Lectures and laboratory sessions for students from the master school. 68 hours, 8 CFU.

2020 - 2021 **Teacher of the Optics and Electromagnetism Laboratory** – School of Physics, *Università degli Studi di Milano–Bicocca*.
Laboratory sessions for students from the second year. 120 hours, 10 CFU.

2019 **Invited lecturer at the 8th School on LHC Physics at the NCP** – National Center for Physics in Islamabad, Pakistan.
Lectures to PhD students on calorimetry and objects reconstruction at the CMS.

2012 - 2013 **Teaching assistant for the class of Elementary Particle Phisics** – Master School of Physics, *Università degli Studi di Milano–Bicocca*.
Lectures to students from the fourth year. *Docente a Contratto*, 32 hours, 5 CFU (prof. A. Ghezzi).

2010 **Teaching assistant for the Optics and Electromagnetism Laboratory** – School of Physics, *Università degli Studi di Milano–Bicocca*.
Laboratory sessions for students from the second year. *Docente a Contratto*, 120 hours, 10 CFU (prof. T. Tabarelli de Fatis).

2008 - 2010 **Teaching assistant for the second year's class of Computer Science and Statistics** – School of Physics, *Università degli Studi di Milano–Bicocca*.
Laboratory sessions for students from the second year. *Docente a Contratto*, 120 hours, 5 CFU (prof. M. Paganoni).

2009 **Tutor for the first year's class of Mechanics and Thermodynamics** – School of Physics, *Università degli Studi di Milano–Bicocca*.
Exercises of mechanics and thermodynamics to students from the first year. 32 hours, 10 CFU (prof. S. Ragazzi).

Selected Talks at Conferences

Oct 2019 *Cerium-doped fused-silica fibers for particle physics detectors*
15th Topical Seminar on Innovative Particle and Radiation Detectors *(IPRD 2019)*, Siena, Italy.

May 2018 *First results from CMS SiPM-based hadronic endcap calorimeter*
18th International Conference on Calorimetry in Particle Physics *(CALOR 2018)*, Eugene (OR), USA.

Jan 2016 *CMS Performance in LHC Run 2*
XXII Cracow Conference on the Physics in LHC Run 2 *(EPIPHANY 2016)*, Kracow, Poland.

Oct 2015 *The data quality monitoring challenge at CMS: experience from first collisions and future plans*
Nuclear Science Simposium and Medical Imaging Conference *(IEEE 2015)*, San Diego (CA), USA

July 2014 *CMS Alignment and Calibration workflows: lesson learned and future plans*
International Conference on High Energy Physics *(ICHEP 2014)*, Valencia, Spain

Oct 2013 *The CMS Data Quality Software: experience and future improvements*
International Conference on Computing in High Energy and Nuclear Physics *(CHEP 2013)*, Amsterdam, Nederlands

Dec 2012 *Performance of the CMS electromagnetic calorimeter and its role in the hunt of the Higgs boson in the* $\gamma\gamma$ *channel*
International workshop on discovery physics at the LHC *(Kruger 2012)*, Kruger Park, South Africa

Jun 2011 *Searches for non-Susy new physics at CMS*
23rd Rencontres de Blois, particle physics and cosmology *(BLOIS 2011)*, Blois, France

Apr 2011 *Search for new physics with high-*p_T *leptons*
XIX International Workshop on Deep-Inelastic Scattering and Related Subjects *(DIS 2011)*, Newport News, VA USA

Jun 2010 *Measurement of the muon stopping power in lead tungstate with the CMS detector*
12th Topical Seminar on Innovative Particle and Radiation Detectors *(IPRD10)*, Siena, Italy

Sep 2009 *Commissioning of the CMS ECAL calibration with muons from cosmic rays and beam dumps*
XCV National Congress of Scuola Italiana di Fisica *(SIF2009)*, Bari, Italy

Outreach and Seminars

Since 2013 Guide of visiting tours for the CMS experiment.

2017 *Dal bosone di Higgs alla nuova fisica con il Large Hadron Collider del Cern di Ginevra*
Seminar in the context of *Il Club della Scienza* at the *Comune di Sesto San Giovanni*

2015 *W/Z identification with the CMS data and W+/W- production asymmetry*
Masterclass for students of the secondary school, introduction and data analysis at the event display

2012 *Dal bosone di Higgs ai neutrini superluminali. Uno sguardo ai recenti risultati dagli acceleratori di particelle*
Seminar at the *Liceo Scientifico Casiraghi* for the students of the last year

2010 *L'acceleratore di particelle del CERN: alla ricerca della particella di Dio*
Seminar at the *Liceo Scientifico Casiraghi* for the students of the last year

2009 *La storia scritta al CERN di Ginevra*
Seminar in the context of *Il Club della Scienza* at the *Comune di Sesto San Giovanni*

Research and professional experience

Context

Since 2007 I have been collaborating to the Compact Muon Solenoid (CMS) experiment taking data at the Large Hadron Collider (LHC). The CMS is a multipurpose detector and its primary goals are currently the study of the characteristics of the Higgs boson and the exploration of new theories beyond the Standard Model of elementary particles. My activity in CMS has focused mainly on three areas:

- instrumental activity for the calorimeters: **commissioning of the electromagnetic calorimeter (ECAL)** from the single channel calibration, to the monitoring of the performance stability, to the tuning of the Monte Carlo (MC) simulation; **re-commissioning of the hadron calorimeter (HCAL)** after the detector upgrade in 2017/2018 and coordination as a **CMS L2 convener of the detector performance group**; coordination of the **electronics simulation working group for the High Granularity Calorimeter (HGCAL) project**;
- physics analyses performing studies of different physics processes both in the **Standard Model and in the SUSY and Exotica** domains;
- coordination as a **CMS L2 convener of the Data Quality Monitoring and Data Certification (DQM-DC)** activity and responsible for the **ECAL and HCAL data quality**.

I have recently joined the effort to develop a MIP Timing Detector (MTD) which is part of the upgrade program of CMS for the High Lumi phase of the LHC.

The calorimetry system of CMS

ECAL commissioning

Since the beginning of my PhD I have been directly involved in the **commissioning phases** of the ECAL detector.
In 2008, in preparation for the LHC startup, I exploited cosmic rays muons data to assess **the validity of the energy scale** in the ECAL barrel. I used the same data to measure the muon specific energy loss in the ECAL crystals as a function of the muon momentum. The first measurement in literature of the **muon critical energy measurement** in the $PbWO_4$ has been published in 2010 [1]. Moreover I exploited the data from beam dump events, collected during LHC commissioning, to study several **calibration strategies for the ECAL endcaps** based on the hypothesis of local uniformity of the energy flux deposited in the endcaps channels. The analysis allowed to achieve an acceptable calibration precision (<5%) already at the start-up. Results are documented in the ECAL performance paper [2].

ECAL calibration and performance

After the LHC startup, I focused on the inter-calibration of the ECAL response using isolated electrons. I contributed in developing a **new inter-calibration method** that makes use of the $E_{ECAL}/p_{tracker}$ measurement for electrons from $W \to e\nu_e$ and $Z \to e^+e^-$ events. In addition I developed a standalone and automated analysis chain to **monitor the stability of the ECAL performance** in real time. I gave a major contribution to the delivery of optimal ECAL calibration conditions for the ~ 20 fb^{-1} of data collected in 2012 [3, 4]: a key ingredient that put CMS in the position to discover the Higgs boson the same year [5].

ECAL simulation

Besides the improvement of the detector performances, I worked at the **optimization of the ECAL MC simulation** for low level observables in order to understand and reproduce the shape of the key variables from data with the highest accuracy as possible. In this context I developed an **analysis framework for the validation of the collision data and of the corresponding Monte Carlo simulations** which is currently used to check and validate the offline reconstruction process for each release of the CMS software. I have been the **ECAL validation responsible** for three years and I took part to the task force that studied and optimized the description of the out-of-time pile up and the electronic noise in the CMS simulation.

ECAL Prompt Feedback Group

Starting from March 2012, for one year, I have been the **convener of the ECAL Prompt Feedback Group**, which supports the data taking activities with fast offline analyses and it is in charge of the certification of the ECAL data, assuring it is suitable for physics analysis. I set up the analysis infrastructure which is currently used and maintained by the ECAL community.

HCAL upgrade

I joined the HCAL community during a very special time: the hadronic calorimeter of CMS has been **upgraded with a two stages approach** during the LHC shutdown in 2017 and 2018. Quartz fibers of the forward calorimeter (HF) are now equipped with a dual anode readout and new front-end electronics that allows to identify and **reject anomalous signals (PMT hits)** thanks to the redundant charge measurement and timing information. The readout of the endcap calorimeter (HE) instead, previously based on hybrid photo detectors (HPD), is now equipped with **silicon photo multipliers (SiPM)**. The new sensors improve the photo detection efficiency by a factor three allowing to measure scintillation light with an increased longitudinal segmentation and making possible a more **accurate modelling and mitigation of the radiation-induced response degradation** [6, 7]. The upgrade of the HCAL had a large impact on the operation of the detector at all levels: from the online software to the signal reconstruction in each cell, from the calibration methods to the simulation of the response. A precise calibration and an accurate description of the new detector is crucial to be able to perform a meaningful measurement of the properties of high level objects such as jets and missing energy (calibration paper under review [8]).

HCAL simulation and re-calibration challenge

I contributed to the implementation and the validation of the new detector layout in the HCAL simulation software and I focused in particular on the re-commissioning of the calibration methods in preparation for collisions. During the last two years, I developed methods to measure the linearity of the response in sub-regions, I was among the main proponents of a calibration method based on the energy released by muons on the HE, I took care of calibrating and characterising the response of the new detector with particular attention to the measurement of the SiPMs dark current. During this delicate time for HCAL, as a DPG convener, I was **responsible of the coordination of the detector calibration effort, the commissioning and the performance of trigger system, energy reconstruction, detector simulation and data quality.** During my guidance, the HCAL successfully collected high quality data until the end of the LHC Run 2.

Phase-II upgrade

Since the beginning of the LHC Long Shutdown 2 (LS2), I moved my focus to the Phase-II upgrade of the CMS endcap calorimetry system and in particular to simulation aspects of the High Granularity Calorimeter (HGCAL). Calorimetry at the High Luminosity LHC (HL-LHC) faces two challenges particularly in the forward direction: radiation tolerance and unprecedented in-time event pileup. To meet these challenges the CMS experiment has decided to construct a High Granularity Calorimeter featuring a previously unrealized transverse and longitudinal segmentation, for both electromagnetic and hadronic compartments. Given my previous experience with the ECAL and HCAL calorimeters of CMS, I have taken the responsibility for the **implementation of the electronics signal description** in the simulation framework of CMS. Of particular importance is the **accurate estimation of the signal evolution over time as a function of the integrated luminosity** that allows to make projections on the expected signal to noise ratio and bandwidth at the detector end of life. These studies, currently ongoing, will provide important inputs to complete the design of the readout electronics systems.

MIP Timing Detector for CMS

The MTD project

The CMS detector is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). In particular, a new **timing detector** will measure minimum ionizing particles (MIPs) with a time resolution of 30-40 ps and hermetic coverage up to a pseudorapidity of $|\eta| = 3$. The precision time information from this MIP Timing Detector (MTD) will **reduce the effects of the high levels of pileup expected at the HL-LHC and will bring new and unique capabilities to the CMS detector**. The central Barrel Timing Layer (BTL) will be based on LYSO:Ce crystals read out with silicon photomultipliers (SiPMs). My current contribution to the development of the MTD detector includes the assembly and characterization of the first barrel detector prototypes and the measurement of their performance in the lab with radioactive or laser sources and at test beams.

Other R&D activity for Particle Detectors

CaPiRe project

My very first contribution to the development of innovative detectors consisted in the assembly and characterization of **Freon-less Resistive Plate Chambers (RPC)** for application to digital hadron calorimetry and neutrino physics. Few prototypes were realized where the quenching of the streamers is controlled mechanically via the insertion of a paper-based honeycomb structure inside the active volume of the chambers instead of using Freon in the gas mixture. This approach eliminates the formation of fluoridric acid that eventually leads to the degradation of the chambers performance.

Cerium-doped fibres

I am currently contributing to the development of scintillating fibres for applications in high-energy physics. Scintillator materials are extremely useful and versatile to detect charged particles, but they suffer from degradation when exposed to moderate levels of radiation. In an attempt to develop radiation-hard scintillating and wavelength shifting fibers, **fused-silica fibres have been doped with cerium for scintillation**. Several prototypes with different geometries have been studied and, during 2017/2018, I took part to the test beam campaigns where irradiated and un-irradiated fibres have been exposed to an electron beam in order to measure their characteristics. Results are encouraging **showing improved light transmission and effective radiation-hardness** [9, 10]. Another interesting feature of these fibres is the abundant Cherenkov light produced by the electromagnetic core of hadronic showers which makes possible to keep track, event-by-event, of the large fluctuation in π^0 production in hadronic showers and to effectively compensate (e/h = 1) the energy measurement. The Cherenkov and scintillation components of the pulse have different time characteristics making possible a simultaneous dual-readout approach in a spaghetti-like calorimeter. Moreover the promptly produced signal from Cherenkov processes could be exploited to obtain **precise timing information**, relevant for applications at colliders in environments with high particle multiplicity.

Physics Analysis

A/H $\rightarrow \tau^+\tau^- \rightarrow e\mu$

As an undergraduate student I performed a feasibility study of the $A/H \rightarrow \tau^+\tau^- \rightarrow e\mu$ decay channel with the CMS detector. In the Minimal Supersymmetric theory (MSSM) the Higgs boson couplings to down-type fermions are enhanced making the $A/H \rightarrow \tau^+\tau^-$ a potential discovery channel for the neutral A/H bosons. Given the similar topology, I have studied the Standard Model decay $Z \rightarrow \tau^+\tau^-$ as a calibration channel to test the algorithms for the signal analysis. I also **developed a new trigger path** with high efficiency of the signal based on the simultaneous requirement of an electron and a muon in the final state with relative small transverse momentum.

W' search

During my PhD, when the first collision data became available, I focused my studies on the **search for the W'** hypothetical gauge boson where it was possible to improve the Tevatron sensitivity with a small amount of data [11]. I developed the analysis framework and worked as one of the main contributors to the exotica non-resonant group being **responsible for the search with electron and neutrino** in the final state. The analysis allowed to exclude the existence of a W' with a mass below 2.5 TeV at the 95% CL in the leptonic decay channel [12].

$H \to \gamma\gamma$

Given my experience and knowledge of the ECAL detector and calibration procedures, in January 2011, I focused on the search for a light Higgs boson in the di-photon channel [13]. My personal contributions, other than the improvement of the ECAL inter-calibration precision at the per-mill level in the central barrel region, concerned mainly the **study and optimization of the primary interaction vertex selection criteria** in different scenarios of pile-up. In order to ensure that the resolution on the opening angle between the photons gives a negligible contribution to the resolution of the reconstructed di-photon mass the interaction point has to be known to better than 10 mm. This target was achieved thanks to the development of discriminating variables based on the kinematic properties of the tracks associated with the vertex and their correlation with the di-photon kinematics. **This analysis has discovered, together with the four lepton final state, a Higgs boson of mass** ~ 125 **GeV**, as announced in July 2012 [5].

Di-Jet searches

At the beginning of the LHC Run 2, I have joined **di-jet search** working group as a data scouting expert. **The data scouting is an innovative technique** that consists in saving the online objects available at the High Level Trigger at high rate in a minimal format. From Run 1 the use of events saved with this technique allowed to set the most stringent limit on the existence of di-jet resonances in the mass region between 500 and 800 GeV [14]. For Run 2, given the excellent performance of the LHC and the increasing of the instantaneous luminosity, I took care of **updating the data scouting strategy** making sure it remains effective. The analysis of the data collected from 2016 to 2018 allowed to set the most stringent limits to date on a number of exotic models that foresee the existence of resonances decaying into two jets (scalar diquarks, axigluons, colorons, excited quarks, W' bosons, Z' bosons, RS gravitons), but more interestingly, **the first limits in the di-jet channel on dark matter mediators have been obtained as functions of dark matter mass and compared to the exclusions of dark matter in direct detection experiments** [15, 16]. Vector and axial-vector mediators below 2.0 TeV were excluded using a universal quark coupling $g_q = 0.25$ and a dark matter coupling $g_{DM} = 1.0$.

Data Quality Monitoring and Data Certification

DQM-DC convenership

Since the beginning of my fellowship at CERN I have been **responsible for the Data Quality Monitoring (DQM) and Data Certification (DC) group** in the context of the Physics Performance and Dataset (PPD) group. As a CMS **L2 convener, I focused on coordinating the activity of the DQM-DC core team in order to set the monitoring strategy for Run 2. Moreover I coordinated all data quality experts from different sub-detector and physics objects groups and I took care of the shifters training**.

DQM upgrade for Run 2

During the LHC Long Shutdown 1 (LS1) the environment in which the DQM operates has undergone fundamental changes. In turn, the DQM system has made significant upgrades in many areas to respond not only to the changes in infrastructure, but also the growing specialized needs of the collaboration. **I leaded the upgrade of the DQM Online workflow**, critical for real-time data quality assessment, giving also a central contribution as **one of the main developers**. On the offline side **I coordinated the effort to make the DQM multithread compliant**. Establishing contacts with an heterogeneous set of communities in the CMS collaboration has been crucial in order to design a system that covers all the use cases [17]. A quantity which is particularly sensitive to spurious detector signals is the $E_{\mathrm{T}}^{\mathrm{miss}}$. Anomalous effects that lead to $E_{\mathrm{T}}^{\mathrm{miss}}$ misreconstruction include dead cells in the ECAL and HCAL, electronics noise, direct particle interactions with the light guides and photomultiplier tubes of the forward calorimeter, contamination of the calibration laser light in the physics events, etc. **The upgraded DQM system allowed to promptly identify and control such effects** [18] ensuring high data taking efficiency and good data quality during the recommissioning phases of CMS after the LS1. The whole infrastructure proved to be very reliable and stable confirming the effectiveness of the new design.

HCAL Data Quality

Building on my extensive expertise in the data quality business, in the second half of 2016 I was appointed **responsible for the data quality and data certification for HCAL**. In this context I have expanded the monitoring strategy for the HCAL detector to include the upgraded detector. The goal was to reliably spot possible problems immediately as they appear which is of great importance particularly during the commissioning period of a new detector.

Machine Learning for Data Quality

In parallel to the standard DQM approach, in the last years I have explored **applications of machine learning (ML) techniques to the data quality business** and I demonstrated, using the full 2016 dataset, how ML algorithms can be used to perform **anomaly detection** and automatize the DQM procedures. I have based my prototype on a semi-supervised model which employs deep autoencoders and is trained using information from all the particles reconstructed in good quality data. Since the anomalies are identified as deviations from the good detector behaviour, the identification of problems is not bound anymore to the experience from the past. The performance was compared against the outcome of the manual certification by experts showing high accuracy and low fake rate in identifying anomalous data. Results have been presented at conferences [19] and are currently being published.

Selected publications:

[1] CMS Collaboration, "Measurement of the Muon Stopping Power in Lead Tungstate", *JINST* **5** (2010) P03007, arXiv:0911.5397. doi:10.1088/1748-0221/5/03/P03007.

[2] CMS Collaboration, "Performance and Operation of the CMS Electromagnetic Calorimeter", *JINST* **5** (2010) T03010, arXiv:0910.3423. doi:10.1088/1748-0221/5/03/T03010.

[3] CMS Collaboration, "Energy Calibration and Resolution of the CMS Electromagnetic Calorimeter in pp Collisions at $\sqrt{s} = 7$ TeV", *JINST* **8** (2013) P09009, arXiv:1306.2016. [JINST8,9009(2013)]. doi:10.1088/1748-0221/8/09/P09009.

[4] CMS Collaboration, "Performance of Photon Reconstruction and Identification with the CMS Detector in Proton-Proton Collisions at sqrt(s) = 8 TeV", *JINST* **10** (2015), no. 08, P08010, arXiv:1502.02702. doi:10.1088/1748-0221/10/08/P08010.

[5] CMS Collaboration, "Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC", *Phys. Lett.* **B716** (2012) 30–61, arXiv:1207.7235. doi:10.1016/j.physletb.2012.08.021.

[6] CMS HCAL Collaboration, “Dose rate effects in the radiation damage of the plastic scintillators of the CMS Hadron Endcap Calorimeter”, *JINST* **11** (2016), no. 10, T10004, arXiv:1608.07267. doi:10.1088/1748-0221/11/10/T10004.

[7] CMS Collaboration, “Improved understanding of dose rate effects in the radiation damage of plastic scintillator tiles”, *under review*.

[8] CMS Collaboration, “Calibration of the CMS hadron calorimeters with proton-proton collision data at $\sqrt{s}$ = 13 TeV”, *under review*.

[9] N. Akchurin, N. Bartosik, J. Damgov et al., “Cerium-doped fused-silica fibers as wavelength shifters”, *Journal of Instrumentation* **14** (jun, 2019) T06006–T06006. doi:10.1088/1748-0221/14/06/t06006.

[10] N. Akchurin, E. Kendir, Å. Yaltkaya et al., “Radiation-hardness studies with cerium-doped fused-silica fibers”, *JINST* **14** (2019), no. 03, P03020. doi:10.1088/1748-0221/14/03/P03020.

[11] CMS Collaboration, “Search for a heavy gauge boson W ’ in the final state with an electron and large missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV”, *Phys. Lett.* **B698** (2011) 21–39, arXiv:1012.5945. doi:10.1016/j.physletb.2011.02.048.

[12] CMS Collaboration, “Search for leptonic decays of W ’ bosons in pp collisions at $\sqrt{s} = 7$ TeV”, *JHEP* **08** (2012) 023, arXiv:1204.4764. doi:10.1007/JHEP08(2012)023.

[13] CMS Collaboration, “Search for the standard model Higgs boson decaying into two photons in pp collisions at $\sqrt{s} = 7$ TeV”, *Phys. Lett.* **B710** (2012) 403–425, arXiv:1202.1487. doi:10.1016/j.physletb.2012.03.003.

[14] CMS Collaboration, “Search for narrow resonances in dijet final states at $\sqrt{(s)} = 8$ TeV with the novel CMS technique of data scouting”, *Phys. Rev. Lett.* **117** (2016), no. 3, 031802, arXiv:1604.08907. doi:10.1103/PhysRevLett.117.031802.

[15] CMS Collaboration, “Search for dijet resonances in proton-proton collisions at $\sqrt{s}$ = 13 TeV and constraints on dark matter and other models”, *Phys. Lett. B* (2016) arXiv:1611.03568. doi:10.1016/j.physletb.2017.02.012.

[16] CMS Collaboration, “Search for narrow and broad dijet resonances in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on dark matter mediators and other new particles”, *JHEP* **08** (2018) 130, arXiv:1806.00843. doi:10.1007/JHEP08(2018)130.

[17] CMS Collaboration, “The CMS data quality monitoring software: experience and future prospects”, *J. Phys. Conf. Ser.* **513** (2014) 032024. doi:10.1088/1742-6596/513/3/032024.

[18] CMS Collaboration, “Performance of the CMS missing transverse momentum reconstruction in pp data at $\sqrt{s}$ = 8 TeV”, *JINST* **10** (2015), no. 02, P02006, arXiv:1411.0511. doi:10.1088/1748-0221/10/02/P02006.

[19] V. Azzolini et al., “Deep learning for inferring cause of data anomalies”, *J. Phys. Conf. Ser.* **1085** (2018), no. 4, 042015, arXiv:1711.07051. doi:10.1088/1742-6596/1085/4/042015.

Milan, 2020.