

REFEREE REPORT

on competition for appointment to the academic position Associate Professor in the professional field 4.1 Physical Sciences (Physics of the Micro-world, High Energies, and Elementary Particles) for the needs of Plovdiv University "Paisii Hilendarski", as announced in the "State Gazette" No. 98 dated January 16, 2025.

with only one candidate Head Assistant Professor Dr. Mariana Filipova Shopova from Plovdiv University "Paisii Hilendarski"

by the member of the scientific jury Prof. Roumen Vassilev Tsenov, Dr.Sci. (Sofia University "St. Kliment Ohridski", retired)

For the competition, Dr. Shopova has submitted a complete set of the required administrative documents such as diplomas, certificates, curriculum vitae, and others. In 2018, the candidate obtained the scientific and academic degree "Doctor" in Physics, awarded by Plovdiv University.

In the competition for Associate Professor, Dr. Shopova presents 18 publications, 7 of which fulfil the requirement for a habilitation work and 10 additional ones, not including the publications on which her dissertation for the degree "Doctor" was based and those upon which she was appointed as Head Assistant Professor in 2019. The publications have a combined impact factor (IF) of 42.17. A list showing 80 citations as of January 17, 2025, is presented.

These data indicate that Dr. Shopova's work is well received in the literature of the field and contributes to its development. This is not surprising, given that these are publications emerging from one of the largest scientific collaborations in the world (CMS), whose results are awaited with interest by researchers in elementary particle and high energy physics. I assume that the candidate encountered some difficulties in excluding self-citations, as the collaboration comprises around 2,500 members, while the scientific community in this field is not particularly large.

The total number of Dr. Shopova's publications as of February 25, 2025, is 836, according to the database *inspirehep.net* - an authoritative source in elementary particle and high energy physics. The citations number 26,943. The h-index is 80. These astronomical numbers are a consequence of the publication policies of large international collaborations at CERN such as CMS, ATLAS, ALICE, LHCb, and others, over which individual members have no control. Such numbers cannot be used to assess the scientific productivity or quality of any individual member of such an international collaboration.

The candidate's research is in the field of experimental particle physics. The work presented in her materials is solely related to the CMS collaboration at the LHC. Dr. Shopova has been a member of this collaboration since 2012.

Dr. Shopova presents both methodological and physical results obtained within the CMS collaboration. The methodological results relate to the analysis of the performance of the Resistive Plate Chambers (RPC) system during data-taking runs. The candidate is also involved in developing proposals to improve the CMS muon registration system in anticipation of the LHC's upcoming luminosity increase. The physical results concern the search for long-lived particles and resonances decaying into lepton pairs, and the registration of the Higgs boson decaying into a pair of muons.

Dr. Shopova is very active in the scientific-organizational activities within the CMS collaboration, particularly related to the muon system of the detector:

- Since 2020, she has been the representative of the RPC system in the Muon Conferences & Publications Board covering the four muon sub-systems.
- Since 2021, she has served as the coordinator of the above group.
- Since 2023, she has been the coordinator of the Detector Analysis Group for the RPC system.

Other scientific-organizational activities include:

- From 2019 to 2024, she has been Bulgaria's representative on the panel of young scientists of the European Committee for Future Accelerators (ECFA) Early-Career Researchers (ECR) Panel, (<https://ecfa.web.cern.ch/ecfa-early-career-researchers-panel>).
- Since 2018, she has been the local organizer for Bulgaria of the CERN International Master classes for high school students, as well as serving as lecturer and mentor.

I mention in detail these organizational commitments because they require considerable time and efforts and significantly contribute both to the success of the CMS collaboration and to achieving new physics results, as well as to the promotion of elementary particle physics in Bulgaria. In this sense, Dr. Shopova's contribution is highly commendable.

Dr. Shopova's main scientific contributions lie in the field of methodology of the physics experiments carried out using a highly complex multi-detector system. I would summarize these contributions as the development of new classifications, methods, designs, and technologies. They include:

- Maintaining the operational status and long-term stability of the CMS RPC system.
In publications [B4-1], [B4-2], [B4-6], [B4-7], [Γ 7-2], [Γ 7-3], [Γ 7-4], [Γ 7-5], and [Γ 7-6], the results from the detector analysis and monitoring of the RPC

system are reported, including its contribution to the L1 trigger of CMS, details on muon reconstruction, and triggering.

The contribution of the entire muon system to recording a sufficiently large volume of quality data for physics analysis and obtaining correct results is documented in [Γ7-8], [Γ7-9], [Γ7-10], and [Γ7-11], as well as in other CMS analyses that involve muons in the final states.

The candidate's personal contribution in these publications lies in data analysis, the timely identification of issues arising in the RPC system's analysis software - as well as other software packages within CMSSW responsible for processing RPC data - and in coordinating various tasks for detector analysis, data processing, and obtaining final results, as well as in training new colleagues.

- Muon trigger and RPC system trigger. Details regarding the operation of the RPC system trigger during various periods are presented in [B4-1] and [B4-6]. The contribution here involves analyzing the raw data used for reconstruction and ensuring the high quality of the recorded data and the stable performance of the RPC system. The candidate serves as the primary editor of the text in work [B4-1].
- Study of RPC Longevity
The latest results from a comprehensive and ongoing study (which continues to this day) on the reliability and longevity of the current RPC chambers for the upcoming data-taking period are shown in [B4-1] and [B4-5]. Two test chambers have been subjected to prolonged irradiation with a cesium source with an activity of 13.5 TBq, with the goal of accumulating in the chambers as much charge as they would receive after the completion of the HL-LHC—that is, after collecting a data volume of 3000 fb^{-1} . At designated intervals, the main characteristics of the chambers are analyzed and compared with results obtained from reference chambers that are not irradiated. The candidate's contribution to this analysis includes participation in assembling some of the detectors, analyzing their operational parameters, evaluating their longevity, and ensuring the collection of quality data during the various test periods at CERN's GIF++ laboratory.
- Upgrade of the CMS Muon System
Activities related to the development and testing of the new, improved RPC detectors (iRPC) and GEM (Gas Electron Multipliers) tracking detectors, as well as the results from these efforts, are described in publications [B4-3], [B4-4], [Γ7-1], and [Γ7-7]. The candidate's personal contribution lies in the assembly and testing of the new detectors, including work at the GIF++ gamma irradiation facility at CERN, as well as in analyzing their operating parameters and the criteria for advancing through various quality control stages.
- Dr. Shopova also declares a significant personal contribution in four publications ([Γ7-8], [Γ7-9], [Γ7-10], [Γ7-11]), in which the lowest up to date upper limits are reported for the production and decay of exotic objects

decaying into two leptons, as well as the measurement of the rare decay of the Higgs boson into two muons in proton-proton interactions at the LHC. The candidate's personal contribution consists of data analysis and ensuring the high quality of the data recorded by the RPC system, which is used in subsequent steps for the identification and reconstruction of muons from the CMS muon system—thereby enabling a quality analysis of events with muons in the final state that led to the reported results.

Here I have a question. In many of the aforementioned articles, the quantity “instantaneous luminosity” is used. It is not clear what the definition of this quantity is and how it differs from the well-defined quantities “luminosity” and “integrated luminosity.” Could Dr. Shopova clarify?

I evaluate Dr. Shopova's personal contributions primarily based on her self-assessment text and on the letter from the head of the CMS RPC system, Dr. Salvatore Buontempo, Director of the Scientific Division of the INFN section in Naples, which confirms the candidate's contribution to the publications submitted for the competition.

I wish to extend my congratulations to Dr. Shopova for the judicious selection of works presented for the competition and for the critical evaluation of her personal contribution in each of them. This is very difficult to accomplish in a collaboration with thousands of members. Dr. Shopova has performed exceptionally well. I am convinced that her stated personal contributions in the submitted works are genuine and accurately reflect her involvement in the creation of the respective publications.

Dr. Shopova is an active participant in several scientific projects funded by the Ministry of Education and Science and the National Science Fund: for the maintenance and operation of the CMS detector (two projects), the National Roadmap for Scientific Infrastructure (three projects), and the MODERN-A project for modernization and partnership through the digitization of the academic ecosystem.

The analysis of the presented information on Dr. Shopova's scientific work convinces me that she is a well-established researcher, capable of independently conducting and leading high-quality scientific research.

The candidate's academic experience in the field exceeds 8.5 years. During this time, Ms. Shopova has delivered lectures on Physics of the Micro-world, Atomic Physics, Nuclear Physics, and has conducted seminars and laboratory exercises on these subjects, as well as on Radiation Physics, Dosimetry and Radiation Protection, Radioecology, Mechanics, Physics 1, and Mathematics 1. She has developed lecture courses in Physics of the Micro-world, Atomic Physics, Nuclear Physics, Radioecology, Radiation Physics, Dosimetry, and Radiation Protection - with the last two taught in English. Throughout this period, her teaching load has significantly exceeded the standard requirements. Under her supervision, 6 diploma theses have been successfully defended. The above-described teaching activity fully meets the

requirements of the Law and of Plovdiv University for appointment to the academic position of “Associate Professor.”

In conclusion, I am convinced that Dr. Shopova fully meets the conditions set forth by the Law on the Development of the Academic Staff and its implementation regulations by the Ministry of Education and Science and Plovdiv University for the appointment to the academic position of “Associate Professor” at the university. I therefore recommend that the Faculty Council of the Faculty of Physics and Technology of Plovdiv University “Paisii Hilendarski” appoints Head Assistant Professor Dr. Mariana Filipova Shopova to the academic position of “Associate Professor” in the faculty.

Sofia, 01 March 2025

Prof. Roumen V. Tsenov, Dr.Sci,