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Letter of Recommendation for Professor Natasa Raicevic to become a Member of the Academy of Sciences and Arts of Montenegro

It is with great pleasure that I recommend Natasa Raicevic, Physics Professor at the Faculty of Natural Sciences and Mathematics at the University of Montenegro, for membership in the Montenegrin Academy of Sciences and Arts. I have known Natasa for 20 years. I was the Spokesperson of the H1 Collaboration, which pursued electron-proton scattering experiments at HERA in Hamburg (Germany), in which Natasa led the University of Montenegro group. I had also been a leader of the physics of the structure of the proton, in which she made seminal contributions. I visited twice her University n Podgorica and thereforw know Natasa very well – both as a scientist and as a person.

I met Natasa Raicevic when she and Professor Slobodan Backovic joined the international research collaboration of the H1 experiment at DESY Institute in Hamburg, which comprised more than 40 research institutes and University groups. They were representing the University of Montenegro. The primary mission of the H1 Collaboration was to measure the internal structure of a proton with a high precision through the deep inelastic scattering of electron (positron) on a proton.

Shortly after we met, in July 2002, Natasa was offered scientific introduction and collaboration at the DESY Institute in Berlin-Zeuthen, in the research group I used to lead. Thanks to her previous knowledge and experience, Natasa easily integrated into the group and incredibly quickly mastered the necessary technical and software skills. The group members were delighted with the amount of and quality of work that she completed within the initial two months of her stay. Subsequently, an intense collaboration continued through her numerous stays at DESY institutes in Berlin and Hamburg and through her work at the University of Montenegro. I quickly identified her as a

reliable partner with great dedication to science and research. Her commitment to science has led to results that were of great importance for the H1 collaboration and the understanding of the internal structure of proton and the theory of strong interaction - Quantum Chromodynamics. Here, I briefly mention some of the most important results she achieved while working in H1 collaboration.

Natasa has participated in the precision measurements of the inclusive deep inelastic neutral current cross sections of scattering (DIS) of positron on proton in the region of low and medium four-momentum transfer squared (Q^2), the resolution of substructure, and extraction of the fundamental proton structure function F_2 and its dependence on the two fundamental DIS parameters, Bjorken x and Q^2.

She also participated in the preparation of a physics program for the so-called *Low Energy Run* with collisions of positrons and protons at reduced proton beam energies from HERA accelerator aiming to provide data for the first measurement of longitudinal structure F_L. After the low energy run was accomplished she took an active role in performing the first measurement of the longitudinal structure function from HERA collider which was a rather challenging task because of large backgrounds and high precision requirements.

Natasa measured the inclusive deep inelastic neutral current scattering cross sections of positron on proton at high inelasticity and small values of Bjorken x. Using these measurements in combination with cross section measurements from HERA I data, the structure function F_L and its dependence on Bjorken x and Q^2 was measured. This was the first measurement of F_L down to $Q^2 = 1.5\ GeV^2$ and Bjorken x down to 10^{-5}.

The here mentioned results were combined with further results from H1 and from the ZEUS experiment to obtain the highest precision measurements of proton structure at HERA which are already part of textbook knowledge.

In addition to the mentioned physics results she achieved, Natasa also worked on improving the software solutions for particle cascade simulation in electromagnetic calorimeter of H1 experiment for detection of scattered electron at small polar angles. Implementation of the so-called *Shower Libraries* significantly improved description of data with the simulation**.** Based on this work Natasa wrote two papers in leading journals in physics computation and instrumentation.

During her years of work within the H1 Collaboration Natasa regularly presented obtained results and technical details at plenary lectures in Hamburg.

After Professor Slobodan Backovic, who initially led the H1 group from University of Montenegro, became the Minister of Education and Science in Montenegro, Natasa became the group leader. Despite being very young for such a leadership position she did a great job. Natasa and I, in collaboration with several German scientific institutions, prepared a scientific project proposal and applied to the German science foundation (DFG) with positive outcome. The project covered a wide range of research to be conducted by the group from the University of Montenegro and the financial resources obtained for the project were exclusively intended for the work of her group. Natasa knew that she could not get appropriate monetary support in Montenegro which is why we tried really hard to obtain funding from an international

project. After three years, we turned to the foundation again and they extended the funding for another three years because they were satisfied with the achieved results. This then also extended the collaboration with Montenegro to an H1 silicon detector project.

Prior to the H1 collaboration, Natasa Raicevic participated in the work of the international CERES collaboration at CERN, the only experiment in which heavy ion interactions were primarily studied through the detection of electron-positron pairs created during the interaction of lead nuclei with gold target.

Natasa worked at CERES as a PhD student and worked in the most prestigious institutions in the field of particle physics. She spent two years at the Joint Institute for Nuclear Research (JINR) in Dubna, which is the leading Russian institution in her field. After that, she did the research at the Physics Institute of the University of Heidelberg for a year. She occasionally went to CERN to work on CERES experiment. Natasa worked on a wide range of research which included studying the emissions of electron-positron pairs but also improving important parts of the software mainly connected with reconstruction of interaction point in collision of the ions which we call vertex. The algorithm for vertex reconstruction had to work as fast as possible (to ensure mass production of events in reasonable time) and to provide high precision reconstruction. To avoid multiple scattering in the target and increase the frequency of the heavy ion interactions, the gold target was not compact but consisted of eight separate disks placed normally, one behind the other, along the beam axis, which further complicated vertex reconstruction. Natasa created a software solution that improved the reconstruction of vertices in every way possible. She wrote a paper on this algorithm that was published in the prestigious journal Nuclear Instruments and Methods A. Natasa belongs to a very small number of researchers in particle physics who had the chance to publish a paper in a journal such as Nuclear Instruments and Methods at such a young age and at the beginning of her career.

Natasa also worked on monitoring and testing of the first level trigger performance at the CERES experiment during her time in Dubna. The trigger system consisted of several detector components, the key ones being the Cherenkov beam counter and low segmented scintillation multiplicity detector. Natasha wrote two technical reports on these detector components which were published in the JINR Rapid Communications.

In both collaborations, Natasha worked on rather demanding physics analysis which resulted in publication of collaboration papers. The papers are among the most cited ones in the collaborations.

Due to her achievements, Natasa has repeatedly been chosen to present collaboration results at international conferences. She gave talks on behalf of the collaboration(s) at the most prestigious conferences in the field. Being selected to publicly present the results strongly reflects the activity and achievements of a researcher in collaboration.

After the H1 collaboration, Natasha worked hard to make Montenegro and the University of Montenegro a full member of one of the LHC experiments at CERN. However, such a feat could only be realized when Montenegro government shows readiness to support participation of Montenegro in CERN monetarily. In July 2017, the Government of Montenegro signed a Memorandum of Understanding with CERN that made University of Montenegro a full member

of the CMS collaboration which represents one of the experiments at LHC. Natasa Raicevic gathered the best students she had at that time and formed a group dedicated to new scientific achievements. The work of this group is based on three doctoral dissertations. Two of them are joint doctoral degrees - one between University of Montenegro and University Paris Saclay in Paris and the other between University of Montenegro and ULB (Université libre de Bruxelles) in Brussels. Thanks to her efforts, the University of Montenegro reached agreements on joint doctoral theses with these world leading universities. For example, on the Shanghai Subject Ranking list, Paris Sacley University is number one in Mathematics and among the top 10 in Physics while ULB is in the top 25. In addition, Natasa also involved University of Montenegro as a beneficiary partner in the international project "The strong interaction at the frontier of knowledge: fundamental research and applications" in 2019. This project has been fully financed by the EU as part of the HORIZON 2020 framework. The full membership in the CMS collaboration also provides Montenegrin scientists with access to all the resources of the collaboration and the chance to collaborate with about 200 leading scientific institutions that are members of the collaboration.

To perform measurements in this field of physics we need devices with superior resolutions which means they have to be based on the most advanced technology. These devices also need to cover as much acceptance as possible and this leads to large scale experiments in modern particle physics. Therefore, in order to obtain significant results in particle physics, a joint effort of a large number of scientists of different profiles is necessary and the road to results is long and demanding, especially if you want to get measurements of the highest possible precision, such as the ones Natasa worked on.

While I cannot personally judge the CERES time, it clearly is a very impressive record. We also collaborated on the development of a post-HERA electron-proton collider, LHeC, where she is a co-author of two major CDR volums which appeared in 2012 and 2020.

Finally, I briefly wanted to highlight that Natasa has achieved outstanding results in the field of elementary particle physics and is on par with the field's leading scientists despite the fact other countries invest significantly more money in experimental research compared to Montenegro. She has been a leader of University of Montenegro groups in two international collaborations in particle physics and these groups have performed rather successfully, largely thanks to her leadership and dedication. It clearly had not been an easy path, also personally, but she has indeed become a distinct, professional, highly recognized scientist with interests beyond particle physics, let alone her major teaching load and achievements over many years. I surely believe she belongs into your Academy.

Should you need any further information about Natasa's work and achievements, please do not hesitate to contact me.