Statement of the Pierre Auger Collaboration as input for the European Particle Physics Strategy Update 2018 – 2020

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Abstract
There is large overlap in the research interests of the European particle physics community and the Pierre Auger Collaboration and there is a remarkable complementarity of the measurement principles and information accessible at accelerators and the Auger Observatory. With this statement, we provide input to the European Particle Physics Strategy Update 2018 – 2020. We strongly encourage very close interaction and collaboration of the particle physics and astroparticle physics communities with respect to experimental, theoretical, instrumental, computational, and organizational activities and indicate the expected benefits for both communities. Examples for joint projects are outlines.

The Pierre Auger Observatory is the worldwide largest and most highly developed air shower detector for the investigation of ultra-high-energy cosmic rays. It is operated by an international collaboration of more than 400 scientists from about 85 institutes and 18 countries. The physics scope of the Auger Observatory is focused on the detection of very-high and ultra-high energy cosmic rays and related physics questions. Central aims of research are the characterisation of the highest energy particles reaching the Earth's atmosphere, with the main aim of unveiling their sources and their nature, the search for ultra-high energy neutrinos and photons, and the study of particle physics at energies and in phase space regions not accessible at man-made accelerators.

Furthermore, the Pierre Auger Observatory is an important instrument in the new age of multi-messenger observations, extending the energy range up to the very highest energies as demonstrated by the results obtained on photon and neutrino diffuse fluxes, which give important information in indirect searches of Dark Matter, or by the study of possible ultra-high energy neutrino signals in correlation with gravitational wave events. The multi-messenger work is done in close interaction with many astroparticle physics collaborations, like IceCube, Antares, Telescope Array, Virgo and LIGO; the Pierre Auger Observatory is an active member of large networks looking for transients and their counterparts, like AMON or DWF.

Already since its foundation, the Pierre Auger Collaboration maintains very close ties with the international particle physics community in general, and CERN in particular. The Pierre Auger Observatory is a CERN recognized experiment; regular Auger-related conferences and schools have been organised at CERN (e.g. ISVHECRI 2002 and 2014, UHECR 2012, ISAPP School 2018). The particle physics questions discussed within the European Strategy for Particle Physics are of direct relevance for the Pierre Auger Observatory. On the one hand, the interpretation of air shower data heavily relies on our knowledge of particle interaction, production, and decay over a very wide range of energies and phase space regions. Particle physics theory and measurements made at accelerators provide indispensable input for understanding extensive air showers. On the other hand, studying air showers offers a window to energies far beyond those accessible at existing accelerators and also emphasizes phase space regions of particle production that are typically not covered in collider experiments. One example is the recent measurement of the proton-air cross section at 57 TeV c.m. energy by the Auger Collaboration. The combination of data from the Auger Observatory with astrophysical information extends the physics reach further to fundamental phenomena, e.g. providing important constraints on theories of quantum gravity involving Lorentz invariance violation.

There is large overlap in the research interests of the European particle physics community and of the Pierre Auger Collaboration and there is a remarkable complementarity of the measurement principles and information accessible at accelerators and the Auger Observatory. Therefore, we want to provide input to the European Particle Physics Strategy Update 2018 – 2020 with this document. In the following, recommendations directly related to the research interests of the Pierre Auger Collaboration are given.

1. We encourage the continuation and deepening of the interaction and collaboration between the astroparticle physics and the particle physics communities. CERN should act as a center for this interaction and should support also in the future a multitude of events related to this

goal, including hosting conferences, workshops, and schools and should also foster a deep long-term collaboration.

2. The interaction between the particle physics and astroparticle physics communities should continue to include dedicated activities in which the particle physics and astroparticle physics communities team up to measure specific quantities as needed for astroparticle physics in accelerator experiments. The unique role of fixed-target and collider experiments for providing data needed in other fields of science, in particular astroparticle physics, needs to be recognized and corresponding measurements should be included in the plans for accelerator-based experiments and data taking. Specifically, we urge CERN to plan an LHC run with light ions, like proton-oxygen, which would fill a very important gap in data needed for air shower physics. Similarly, fixed-target and collider measurements with very good forward coverage for hadron production will be very valuable.

3. Joint theoretical studies of questions in the overlap region between particle and astroparticle physics will be of fundamental importance for making scientific progress. We encourage the interaction of the two communities and the engagement in inter-disciplinary research into theoretical and phenomenological questions. One example is the development and tuning of hadronic event generators as needed in high-energy physics and cosmic ray simulations. Both theoretical and experimental work will be needed to address the well-established muon discrepancy in air showers. While this muon excess relative to predictions is most likely related to shortcomings in simulating hadronic particle production it could also indicate new particle physics at energies beyond the reach of LHC. Moreover, air showers provide a very good testbed for searching for physics beyond the Standard Model for various classes of models, production of including micro-black holes and other heavy states.

4. We support the close collaboration of the particle and astroparticle physics communities in the development of particle physics detection technologies and instrumentation for both particle physics and astroparticle physics experiments. The applied detection methods and corresponding instrumentation are very similar and often also complementary for these experiments and joint development efforts will provide large synergies in developing future detectors.

5. Modern particle and astroparticle physics experiments and advanced theoretical simulations require very powerful, large-scale computing and data storage facilities. We encourage the particle physics community to collaborate with the astroparticle physics community in developing the needed next-generation computing and storage facilities. These facilities should be made available to all relevant scientific communities for contributions and scientific use.

6. We encourage the close collaboration of the particle and astroparticle physics communities in attracting and educating young scientists and in supporting their scientific career. The related joint efforts should also include science communication and outreach activities that cover both particle and astroparticle physics.