DESCRIPTION FOR THE GENERAL PUBLIC (IN ENGLISH)

University of Łódź participates in the biggest in the world experiment Pierre Auger Observatory investigating the ultra-high-energy cosmic rays (UHECR) (E $>10^{19}$eV). The origin of the particles coming from the space with so giant energies remains a mystery. Their sources and acceleration mechanism are still unknown. The UHECR remains still one of the biggest puzzle of a present astrophysics.

The Pierre Auger Observatory can address the most fundamental questions about the nature of the highest-energy cosmic rays. We propose improvements and additions to accomplish this in the period from 2015 to 2023. Auger has observed clearly both a strong cosmic-ray flux suppression at the highest energies and a sharp spectral transition near $10^{18.7}$ eV (the ankle). Presently it is not possible to determine whether the suppression is due to energy losses in transit (the GZK effect) or if it reveals the maximum energy of the source accelerators. The primary objective of the proposed upgrade is to provide an answer to this question.

It is evident that this puzzle must be resolved in order to identify sources or source regions. This has been the central goal of the Auger Observatory and indeed of all cosmic ray research. The key lies in better identification of the primary composition, especially extending to the highest energies. An event-by-event understanding of the identities of the particles will elevate the quality of several analyses, including

a) anisotropy study, by using only small-Z particles;
b) seeking evidence of a maximum accelerator energy (E ~ Z), by observing the primary mass increasing as the flux declines.

Moreover, explicit experimental confirmation of the existence of even a small (~10%) flux contribution of light elements at the highest energies will be a decisive ingredient for assessing the physics potential of existing and future cosmic ray, neutrino, and gamma-ray detectors.

Specific aims of the upgrade are:

- We plan to extend the existing measurements of composition-sensitive observables to higher energy to search for the rigidity-dependent suppression of the flux of individual mass groups and will determine the corresponding maximum injection energy of the single source or source population. Determining the mass composition of ultra-high energy cosmic rays is closely related to, and crucially depends on, understanding extensive air showers and hadronic interactions. Estimating the number of muons in air showers from Auger data, a discrepancy between the observed and expected muon numbers is found. Therefore the third key science objective will be the study of extensive air showers and hadronic multi-particle production. This will include the exploration of fundamental particle physics at energies beyond those accessible at man-made accelerators and the derivation of constraints on new physics phenomena, such as Lorentz invariance violation or extra dimensions.
- We will use event-based composition estimators to establish whether a proton contribution of at least 10% exists in the primary cosmic ray flux at 5.5×10^{19} eV and use this population of light particles to search for sources of ultra-high energy cosmic rays (proton astronomy). The search for a flux contribution of protons up to the highest energies will be the second key science objective. The measurement of the fraction of protons is the decisive ingredient for estimating the physics potential of existing and future cosmic ray, neutrino, and gamma-ray detectors. Prospects for proton astronomy with future detectors will be determined. Moreover, the flux of secondary gamma-rays and neutrinos due to proton energy loss processes will be predicted.
- We will increase the sensitivity of the Auger Observatory to primary photons at energies between 10^{17} to 10^{19} eV to seek photons from GZK interactions. Such an observation can either prove or disprove the hypothesis of a proton-dominated composition masked by a rapid change of hadronic multi-particle production above $\sqrt{s} = 70$ TeV.
- The increased composition sensitivity of the Auger Observatory will also allow us to study features of hadronic interactions at energies well beyond those of LHC. This is valuable in and of itself but also required to interpret measurements of the highest energy air showers.
- The upgrade of the Auger Observatory is to elucidate the origin of the flux suppression and the mass composition at the highest energies, i.e. the differentiation between the energy loss effect due to propagation and the maximum energy of particles injected by astrophysical sources. This is a natural evolution and major step forward from the original objective of the Pierre Auger Observatory, which was motivated primarily by the question of the existence of a GZK-like flux suppression. Understanding the origin of the flux suppression will provide fundamental constraints on the astrophysical sources, including whether these are predominantly of galactic or extragalactic nature, and will allow much more reliable estimates of neutrino and gamma-ray fluxes at ultra-high energy for which we will continue to search.