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Ultra-high energy cosmic rays: where do we stand 50 years after their first detection?

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Ultra-high energy cosmic rays (UHECR, $E > 10^{18}$ eV) can be studied only through the giant air-showers they produce in atmosphere. First UHECRs were detected 50 years ago by the pioneering Volcano Ranch air-shower array. Since then, many more UHECR data have been collected, by larger and higher quality experiments that have followed each other in half a century. We make a retrospective survey of the technical progress that has lead to the construction of the two largest UHECR experiments in the world, the Telescope Array and the Pierre Auger Observatory, whose data currently dominate from the Northern and Southern hemispheres, respectively. We review the results of their measurements on the UHECR energy spectrum, primary composition and distribution of arrival directions. While important advances in understanding UHECR have been made in 50 years, new challenging questions have been opened too. We discuss the perspectives for answering them in the future.

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