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Deep Learning for Cosmic-Ray Observatories

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Ultra-high energy cosmic rays (UHECRs) are the most energetic particles found in nature and originate from extragalactic sources. These particles induce extensive air showers when propagating within the Earth's atmosphere. Cosmic-ray bservatories like the Pierre Auger Observatory measure such air showers using large arrays of surface-detector stations and luorescence telescopes. The reconstruction of event-by-event information sensitive to the cosmic-ray mass is a challenging task and so far, mainly based on the shower shape as measured by fluorescence detector observations with their duty cycle of about 15%.

Recently, significant progress has been made in multiple fields of machine learning using deep neural networks and associated techniques. Applying these new techniques to cosmic-ray physics opens up possibilities for improved reconstructions, including an event-by-event estimation of the cosmic-ray mass using the surface-detector exclusively, exploiting the 100% duty cycle.

In this contribution, we present deep learning-based algorithms applied in the context of cosmic-ray physics. Beside supervised learning for event reconstruction, we investigate methods for understanding the decisions of deep networks which are trained on physics-related tasks. Finally, we discuss strategies for reducing differences between data and physics simulations using adversarial frameworks.

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