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Hadronic interaction studies at the Pierre Auger Observatory

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The muon content of extensive air showers produced by the ultra-high energy cosmic rays is an observable sensitive to the composition of the primary particle and to the properties of hadronic interactions driving the air-shower cascade. We present different methods to estimate the muon number at the ground and the muon production depth using measurements of the longitudinal, lateral, and temporal distribution of particles in the air showers recorded by the Pierre Auger Observatory. The results, obtained at ˜140 TeV c.m. energy for proton primaries, are compared to the predictions of LHC-tuned hadronic interaction models for different primary masses. The models exhibit a deficit in the predicted muon content and the combination of these results with other independent mass composition analyses (such as Xmax) provides them with additional constraints. With the hybrid data it is possible to measure the cross section of proton-air collisions at energies far beyond the reach of the LHC. The proton-air cross section is estimated in two energy bins around ˜10ˆ18 eV, chosen for maximal statistics and significant primary proton fraction. In this intervals only the 20% of the most proton-like events are considered to eliminate contamination from higher nuclei. We discuss the model-dependent uncertainties of the measurements.

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