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Estimating the mass of cosmic rays by combining radio and muon measurements

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The Auger Engineering Radio Array (AERA) is a radio detector at the Pierre Auger Observatory and it is dedicated to measure the radio emission of cosmic-ray air showers. AERA is co-located with the underground muon detectors of the Auger Muons and Infill for the Ground Array (AMIGA). This provides a perfect setup to experimentally test the benefits of combining muons and radio emission for estimating the primary mass. Cosmic-ray induced air showers consist to a large fraction of electrons and muons. The size of these shower components shows an opposite dependency on the mass of the primary cosmic-ray particles. Thus, combining them allows to estimate the mass. The size of the electromagnetic component can be measured in a calorimetric way via the radio emission produced in the atmosphere. The magnitude of the muonic component can be measured counting particles under ground. We have investigated the combination of radio measurements with muon measurements using air-shower simulations. We compared the performance for mass separation of this new method to alternative methods in which the electrons and muons are measured with particle detectors at the surface. For showers with zenith angles below 50° the new method is of comparable performance, and for showers more inclined than 50° it is clearly superior. In particular in inclined showers, the electrons are mostly absorbed in the atmosphere before reaching the surface, but the radio emission is not. Therefore, measuring the radio signal in addition to the muons significantly improves the mass sensitivity.

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