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MC study of proton-Nitrogen collisions at RHIC for cosmic-ray physics

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To understand the origin of high-energy cosmic rays, many experiments were carried at ground level, thereby observing air showers. Many measurements confirm a steepening and a flattening of the all-particle spectrum at $10^{15.5}$ and $10^{18.5}$ eV, that are called 'knee' and 'ankle', respectively. Both are considered to be the indices of change in propagation or origin of cosmic rays. Despite the high statistics, interpretation of the results depend strongly on the hadronic interaction model used in the Monte Carlo calculation which has larger uncertainties than the statistical errors. Chemical composition of cosmic ray (from proton to iron nucleus) is one interest of astroparticle physics, but results are not settled yet. Calibration of interaction models is an urgent need for air shower measurements.
LHCf experiment has measured data of the forward region in proton-proton collision at $\sqrt{s} = 0.9$, 7 and 13 TeV and proton-lead collision at $\sqrt{s_{NN}} = 5.02$ TeV at LHC. Nuclear effect must be well understood, since air shower consists of interactions between cosmic ray (proton to iron nucleus) and the atmosphere (mainly nitrogen); lead and gold are too heavy target. Unfortunately, no high energy collision of light ion has been provided. RHIC and LHC are good candidates that can provide such collisions. We focus on the result expected with proton-nitrogen inelastic collision at $\sqrt{s_{NN}} = 200$ GeV (10^{14} eV in lab frame) where we use the LHCf detector in the forward region ($\eta > 6$) of the proton-remnant side at RHIC. We compare the energy spectrum with that of proton-proton inelastic collision at $\sqrt{s}$=200 GeV to evaluate the nuclear effect. A MC calculation shows that it is possible to discriminate nuclear effect incorporated in some models widely used in air shower measurements and demonstrates that it can be the first good test to evaluate air shower.

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