EFFECT OF LORENTZ INVARIANCE VIOLATION ON HADRONIC MULTIPARTICLE PRODUCTION AND ULTRA-HIGH-ENERGY EXTENSIVE AIR SHOWERS

Luan Arbeletche, Rodrigo Guedes Lang

1 PROBLEM STATEMENT

A central open problem in astroparticle physics is the characterization of the cosmic-ray spectrum at ultra-high energies in terms of its mass composition. Measurements in this regard are performed after the detection of extensive air showers and the posterior interpretation of observables through comparison with simulations, a process which is largely affected by uncertainties in the modeling of multiparticle production in hadronic interactions. Moreover, as energies involved in the interaction between the primary cosmic ray and atmosphere nuclei exceed those probed in particle colliders, it is likely that the observed showers are incorporating effects from physics scenarios not considered by the current hadronic interaction models. Among many possibilities of exotic physics scenarios, some theories predict that the Lorentz invariance paradigm may be broken above some energy threshold which would ultimately lead to a new regime of particle diffusion, decay, and interaction in the atmosphere during the evolution of extensive air showers. In particular, the multiplicity of secondary particles and their energy spectra produced in the first, most energetic, interaction may be affected by the changes in the energy-mass dispersion relation typically expected from physics scenarios with Lorentz invariance violation (LIV).

We propose in this work to perform a simulation-based analysis of the effect of changing the energy spectrum and multiplicity of secondary particles produced in the first interaction of ultra-high-energy cosmic rays with atmospheric nuclei in the search for observables that are most sensible to this effect. In a first step, we intend to quantify the extent to which shower observables are affected in a LIV scenario when current experimental constraints to LIV theories are taken into account. In a second moment, reversely, we propose to explore shower observables that can be used to constrain or even identify LIV scenarios.

2 EXPECTED OUTPUT

A publication tackling the following questions:

- How are the characteristics of secondary particles produced in hadronic interactions changed in case Lorentz invariance is violated?
- How would such effect modify shower evolution in the regime of ultra-high energies?
- Does the presence of LIV imply a new interpretation of the mass-composition problem in the ultra-high-energy regime in view of the current data?
- Is it possible to use data from current experiments (e.g. Pierre Auger Observatory) to constrain LIV scenarios?

3 REQUIREMENTS

- Description of hadronic multiparticle production in hadronic interactions in a scenario of Lorentz invariance violation (Rodrigo);
- Implementation of the modified particle spectrum in the air shower simulation code (Luan);
- Computing resources for generating the LIV-case and non-LIV-case simulations for comparison between both (Santos Dumont and ECAP cluster).