# Executive Summary CR Session

**Workshop "Results and prospects of forward physics at the LHC: Implications for the study of diffraction, cosmic ray interactions, and more", summary of the cosmic-ray session**

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### CR Organization panel:

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### Introduction

The goal of the workshop was to discuss various aspects of forward physics at the LHC and, in particular, to review the status of the understanding of cosmic-ray showers, both from data and from MC simulations, and to define the LHC measurements that are needed to improve the precision of existing air shower models. Over 100 participants, equally distributed between the LHC and cosmic ray communities, attended the workshop.

### Monte Carlo generators for modeling hadronic processes in air showers

Despite a great wealth of presented material, and intense discussions, the status of hadronic generators for air-shower physics with respect to LHC data is not sufficiently clear at the moment. While a large part of the available LHC results have been used for data to MC comparisons, the model tuning is not finalized yet and the comparisons are not sufficiently documented yet.

Hence we propose to form a task force consisting of mostly cosmic-ray physicists (both from experiment and theory), but also physicists engaged at the LHC, to document the status of hadronic air shower generators in view of the LHC run 1 data (as far as it is analyzed). The workshop organization panel shall propose the task force membership, where some panel members are likely going to participate in the task force, too. The goal of the task force is to produce a report that details the current status of Monte Carlo to data comparisons and identifies possible additional LHC measurements and running conditions that would be necessary to improve the modeling of hadronic processes in air showers. The document shall comprise demonstrations of the actual impact of these additional data on hadronic air shower generators and corresponding predictions for air shower observables. Furthermore the document should list future measurements of importance that should be planned for the time after the LHC shutdown. We propose that this document is to be delivered within 3-4 months from now.

### Light ion LHC running

Any comparison of current LHC data to Monte Carlo generators modeling the first and the subsequent high-energy interactions of cosmic rays and air in the Earth's atmosphere requires, at the moment, extrapolations from proton-proton, proton-lead, lead-lead initial states to particle combinations relevant for interactions in air showers (protons, pions, kaons and nuclei up to iron colliding with oxygen, carbon or nitrogen nuclei). Such extrapolations introduce uncertainties, as they require the use of models, for example the so-called Glauber model, to convert observables of proton-proton collisions to quantities applicable to proton-nuclei collisions. A clear wish was formulated by cosmic-ray physicists to mitigate these uncertainties from extrapolations by recording data with light ion LHC running (primarily proton interactions with light nuclei such as carbon, oxygen or nitrogen, but also other combinations such as carbon-carbon or iron-carbon interactions would be very interesting), thereby allowing for more direct data to Monte Carlo comparisons.

An informal presentation by an LHC accelerator physicist suggested that

   a) Oxygen or nitrogen running is technically feasible and would require at most some 8 to 12 weeks of parasitic commissioning.
   b) The scheduling is the big challenge given the large and diverse LHC physics program.

c) Given the scheduling issue, light-ion running is unlikely to happen on short timescales (before the next long shutdown in 2018) unless such a running mode is strongly supported by the LHC experiments themselves.

Discussions between the cosmic-ray and heavy-ion communities of the LHC experiments about such light-ion runs are not only desirable but essential to outline a possible running plan that can be considered by the CERN scientific committees and management.

## Future accelerator-based measurements at CERN

In most of the cases, the measurement of observables of relevance to model tuning for cosmic-ray interactions and low transverse momentum QCD physics will require short low-luminosity runs with negligible event pile-up. It is therefore of great importance for the improvement of MC generators in general (not only for the cosmic-ray community) to preserve the option of operating the LHC in low-luminosity mode during short special runs.

In addition to the measurements made with the LHC experiments, data from fixed-target experiments are also very important for improving the reliability of air shower predictions (as demonstrated at the workshop with NA61 analyses).

## Underground cosmic-ray measurements by LHC detectors

Underground measurements of multiplicities or charge ratios of muons produced by cosmic rays in the atmosphere as presented by ALICE or OPERA generated a lot of interesting discussions. In particular events with very large muon multiplicities measured underground are not easily reproducible with MC generators. It was clearly recognized that such measurements increase the physics output of LHC detectors and provide very valuable cosmic-ray measurements that probe Monte Carlo generators. However, it is obvious that sufficient manpower and resources are currently not available, in particular among the LHC experiments, to pursue such measurements in appropriate detail. Support of or collaboration with the astroparticle physics community is needed to carry out and to analyse such measurements in future. Dedicated cosmic-ray campaigns could be performed during LHC shutdown periods and should ideally be combined with surface detector arrays (e.g. scintillators) to measure air shower parameters (core location etc.) that are crucial for the interpretation of high-multiplicity events.