

## The Cosmic-Ray Program of the NA61/SHINE facility at the CERN SPS

---

**Michael Unger\*** for the NA61/SHINE Collaboration<sup>†</sup>

*Karlsruhe Institute of Technology (KIT), Postfach 3640, D-76021 Karlsruhe, Germany*

*E-mail: [michael.unger@kit.edu](mailto:michael.unger@kit.edu)*

NA61/SHINE is a unique spectrometer for the measurement of hadronic interactions at fixed-target energies that are of particular interest for cosmic ray physics.

In this talk we will present the new results from our 2009 data-taking campaign on particle production in  $\pi^-$ -C interactions at 158 and 350 GeV/c. These interactions are relevant to understand the final stages of ultrahigh-energy cosmic-ray air showers. Our measurements include the production of pions, kaons, (anti-)protons and rho mesons. We will discuss the impact of these results on the interpretation of cosmic-ray data.

Furthermore we will report on new data on the fragmentation of carbon nuclei. A one week pilot run with data taking of carbon on polyethylene and carbon at a beam energy of 13 GeV/nucleon took place at the end of of 2018. The aim of this run was to demonstrate capabilities of the experiment to perform high-precision measurements of nuclear fragmentation cross sections needed for the understanding of secondary-to-primary cosmic-ray flux ratios, such as the boron-to-carbon ratio. Preliminary results on the data quality and identification of beam nuclei and fragmented nuclei will be presented.

*36th International Cosmic Ray Conference -ICRC2019-  
July 24th - August 1st, 2019  
Madison, WI, U.S.A.*

---

\*Speaker.

<sup>†</sup><http://shine.web.cern.ch/content/author-list>

The full version of this contribution will be uploaded after the presentation.

We will present an improved measurement of the production of antiprotons in  $\pi^-$ -C interactions with the NA61/SHINE experiment [1]. A good knowledge of this reaction is crucial for the prediction of muons in air shower. With this measurement will conclude our extensive studies [2, 3, 4, 5, 6, 7, 8] of pion-induced hadronic interactions for air shower physics.

A pilot run [9] on the measurement of nuclear fragmentation cross sections for cosmic-ray propagation studies took place in December 2018. We will present preliminary results on the production of Boron in C-p interactions and discuss a proposed future measurement campaign of fragmentation cross sections [10].

## References

- [1] N. Abgrall *et al.*, [NA61/SHINE Collab.], “NA61/SHINE facility at the CERN SPS: beams and detector system,” *JINST* **9** (2014) P06005.
- [2] I. Mariş, [NA61/SHINE Collab.], “Hadron Production Measurements with the NA61/SHINE Experiment and their Relevance for Air Shower Simulations,” *Proc. 31st ICRC* (2009) 1059.
- [3] M. Unger, [NA61/SHINE Collab.], “Hadroproduction Measurements with NA61/SHINE for the Understanding of Extensive Air Showers,” *Proc 32nd ICRC* **5** (2011) 67.
- [4] H. Dembinski, [NA61/SHINE Collab.], “Measurement of hadron-carbon interactions for better understanding of air showers with NA61/SHINE,” *Proc. 33rd ICRC* (2013) 688.
- [5] A. Herve, [NA61 Collab.], “Results from pion-carbon interactions measured by NA61/SHINE for better understanding of extensive air showers,” *PoS ICRC2015* (2016) 330. [34,330(2015)].
- [6] A. Aduszkiewicz *et al.*, [NA61/SHINE Collab.], “Measurement of meson resonance production in  $\pi^- + C$  interactions at SPS energies,” *Eur. Phys. J.* **C77** no.~9, (2017) 626.
- [7] R. R. Prado, [NA61/SHINE Collab.], “Measurements of Hadron Production in Pion-Carbon Interactions with NA61/SHINE at the CERN SPS,” *PoS ICRC2017* (2018) 315.
- [8] R. R. Prado, [NA61/SHINE Collab.], “Recent results from the cosmic ray program of the NA61/SHINE experiment,” *EPJ Web Conf.* **208** (2019) 05006.
- [9] A. Aduszkiewicz *et al.*, [NA61/SHINE Collab.], “Feasibility Study for the Measurement of Nuclear Fragmentation Cross Sections with NA61/SHINE at the CERN SPS,” 2017. CERN-SPSC-2017-035 ; SPSC-P-330-ADD-9.
- [10] A. Aduszkiewicz, [NA61/SHINE Collab.], “Study of Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS: Early Post-LS2 Measurements and Future Plans,” 2018. CERN-SPSC-2018-008. SPSC-P-330-ADD-10.