IL NUOVO CIMENTO **42 C** (2019) 211
DOI 10.1393/ncc/i2019-19211-x

COLLOQUIA: IFAE 2018

Cosmic collisions with the LHCb experiment

S. MARIANI on behalf of the LHCb COLLABORATION

Università di Firenze e INFN, Sezione di Firenze - via G. Sansone 1, 50019 Sesto Fiorentino (FI), Italy

received 31 January 2019

Summary. — The antiproton production cross-section in p-He collisions at $\sqrt{s_{\rm NN}} = 110\,\text{GeV}$ is measured with the LHCb experiment at CERN. The results are important for the interpretation of the data collected by the space-borne experiments PAMELA and AMS for the antiproton fraction in cosmic rays. The potential of an indirect observation of dark matter is presently limited by the uncertainty on the antiproton production in interactions between cosmic rays and the interstellar medium.

1. – Introduction

1˙1. *Motivations*. – The measurement of the antimatter fraction in Cosmic Rays (CRs) is performed with increasing precision by the space-borne PAMELA and AMS-02 experiments [1, 2]. The collected data are compared to the expected antimatter abundance produced by high-energy collisions between a CR particle and the interstellar gas, which is mainly composed of hydrogen and helium. An excess could be explained through a primary source as a dark-matter annihilation or decay process to an ordinary particle-antiparticle final state. In the measurement of the antiproton-to-proton flux ratio some intriguing tensions with the expectations are emerging [3], but large theoretical uncertainties limit the strength of any conclusion. Among these, the cross-section $\sigma(p\text{He} \to \bar{p}X)$ is obtained with a 20–30% uncertainty from extrapolations using p-p or p-C collision data since no direct measurements exist.

1˙2. *Detector*. – Conceived to perform heavy-flavour measurements, the LHCb experiment at CERN [4, 5] is a single-arm spectrometer. The detector geometry, covering the forward direction, is well suited to the fixed-target configuration. The helium gas can be injected in the LHC beam pipe thanks to SMOG (System for Measuring Overlap with Gas [6]) and the 6.5 TeV LHC protons collide with at-rest He nuclei for a nucleon-nucleon centre-of-mass energy $\sqrt{s_{\rm NN}} = 110\,\text{GeV}$. The LHCb excellent vertexing, tracking and particle identification capabilities allow to reconstruct and identify the antiprotons produced in the p-He collisions.

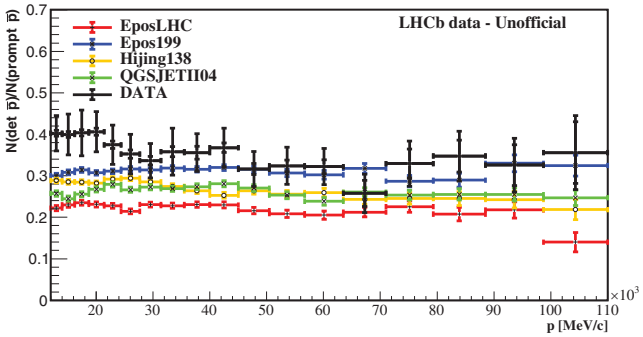

Fig. 1. – Comparison of the experimental results with predictions from the main models of hadronic interactions for the detached-to-prompt antiproton ratio as a function of the $\bar{p}$ momentum.

2. – Measurement

Antiprotons are produced directly in the p-He collision or in strong or electromagnetic decays (prompt $\bar{p}$) or via the anti-hyperons $\overline{\Lambda^0} \to \bar{p}\pi^+$ and $\overline{\Sigma^+} \to \bar{p}\pi^0$ weak ones (detached $\bar{p}$).

2˙1. *Prompt component.* – The dominant prompt $\bar{p}$ component production cross-section is measured in kinematic bins in the fiducial range $p \in [12, 110]\,\mathrm{GeV}/c$, $p_T > 400\,\mathrm{MeV}/c$ [7]. Antiprotons are required to originate near the p-He vertex and are counted performing a fit to the distribution of particle identification variables determined from the RICH response. Since SMOG is currently not equipped with precise pressure gauges, the luminosity is indirectly calculated from p-e elastic scattering events. This process is precisely known and has a distinct signature with a low-energy and isolated electron in the LHCb acceptance.

2˙2. *Detached component.* – The detached $\bar{p}$ component is expected to represent 25–30% of the total and a dedicated measurement of $R = \sigma_{\mathrm{DET}}/\sigma_{\mathrm{PR}} = N^{\mathrm{DATA}}_{\mathrm{DET}}/N^{\mathrm{DATA}}_{\mathrm{PR}} \cdot \varepsilon_{\mathrm{PR}}/\varepsilon_{\mathrm{DET}}$ is being performed. In each kinematic bin, all $\bar{p}$ are reconstructed and classified as prompt or detached according to their impact parameter (IP) with respect to the primary vertex. The $\bar{p}$ abundances $N^{\mathrm{DATA}}_{\mathrm{PR,DET}}$ are obtained performing a fit to the IP distribution; the efficiencies $\varepsilon_{\mathrm{PR,DET}}$ are estimated from simulation. As shown in fig. 1, the preliminary results confirm the kinematic dependence predicted by the most important models of hadronic interactions but are significantly larger.

3. – Conclusion

The first ever measurement of the $\bar{p}$ production cross section in p-He collisions at $\sqrt{s_{\mathrm{NN}}} = 110\,\mathrm{GeV}$, including the strange particle decays contribution, is being performed and it is expected to have a sizeable impact on the prediction for $\bar{p}$ abundance in CRs.

REFERENCES

[1] PAMELA Collaboration, *JETP Lett.*, **96** (2013) 621.
[2] AMS Collaboration, *Phys. Rev. Lett.*, **117** (2016) 091103.
[3] Giesen G. *et al.*, *JCAP*, **09** (2015) 23.
[4] LHCb Collaboration, *JINST*, **3** (2008) S08005.
[5] LHCb Collaboration, *Int. J. Mod. Phys. A*, **30** (2015) 1530022.
[6] LHCb Collaboration, *JINST*, **9** (2014) P12005.
[7] LHCb Collaboration, LHCb-CONF-2017-002 (2017).