Antiproton production from cosmic-ray interactions and its compatibility with AMS-02 data

Motivation and Overview

Recent cosmic-ray (CR) studies have claimed the possibility of an excess of antiproton data over the predicted flux at ~ 10 GeV, which can be the signature of dark matter. Nevertheless, this excess is subject to many uncertainties related to the evaluation of the antiproton spectrum produced from spallation interactions of CRs.

Method and novelty

We perform combined analyses of the secondary CRs B, Be and Li and antiprotons ($\bar{p}$). The spectra of these CRs is evaluated with the DRAGON2 code (Ref. [1]), assuming a diffusion-reacceleration model.

Propagation parameters are inferred from a fit to experimental data by means of the Markov-Chain Monte Carlo (MCMC) procedure based in Ref. [2].

Main novelty: We incorporate scale factors to renormalize the cross sections parametrizations of B, Be and Li production ($\mathcal{S}_B$, $\mathcal{S}_{Be}$, $\mathcal{S}_{Li}$), allowing us to adjust the grammage to improve the predicted $\bar{p}/p$ ratio.

The MCMC routine minimizes likelihood from the fit of:

- **p̄/p, B/C, B/O, Be/C, Be/O** flux ratios, to constrain the diffusion coefficient (D_0/H, η, δ) and the Alfvèn speed V_A.
- **Be/B, Li/B, Li/Be** flux ratios (which mainly allow us setting the values of the scaling parameters, see Ref. [3])
- **^{10}Be/Be** and **^{10}Be/^{9}Be**, to constrain the halo height, H.

Propagation parameters and relevant CR spectra

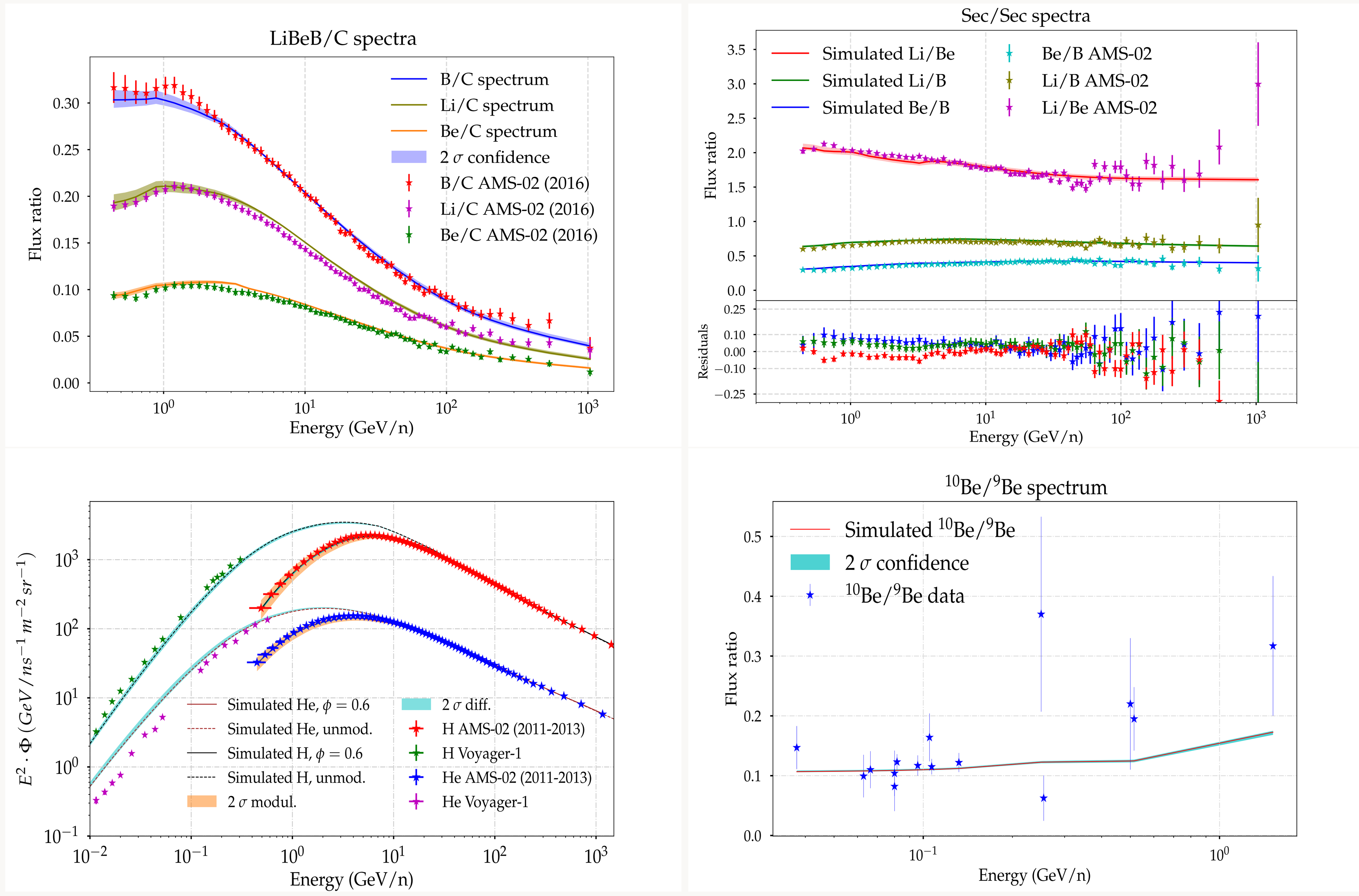


Figure: Relevant CR spectra obtained from the combined analysis and compared to experimental data. Error bands represent the 2σ statistical uncertainty in the determination of the propagation parameters and the lower-left panel also shows solar modulation uncertainties. The injection parameters are tuned to reproduce AMS-02 data on primary CRs at each step of the MCMC procedure.

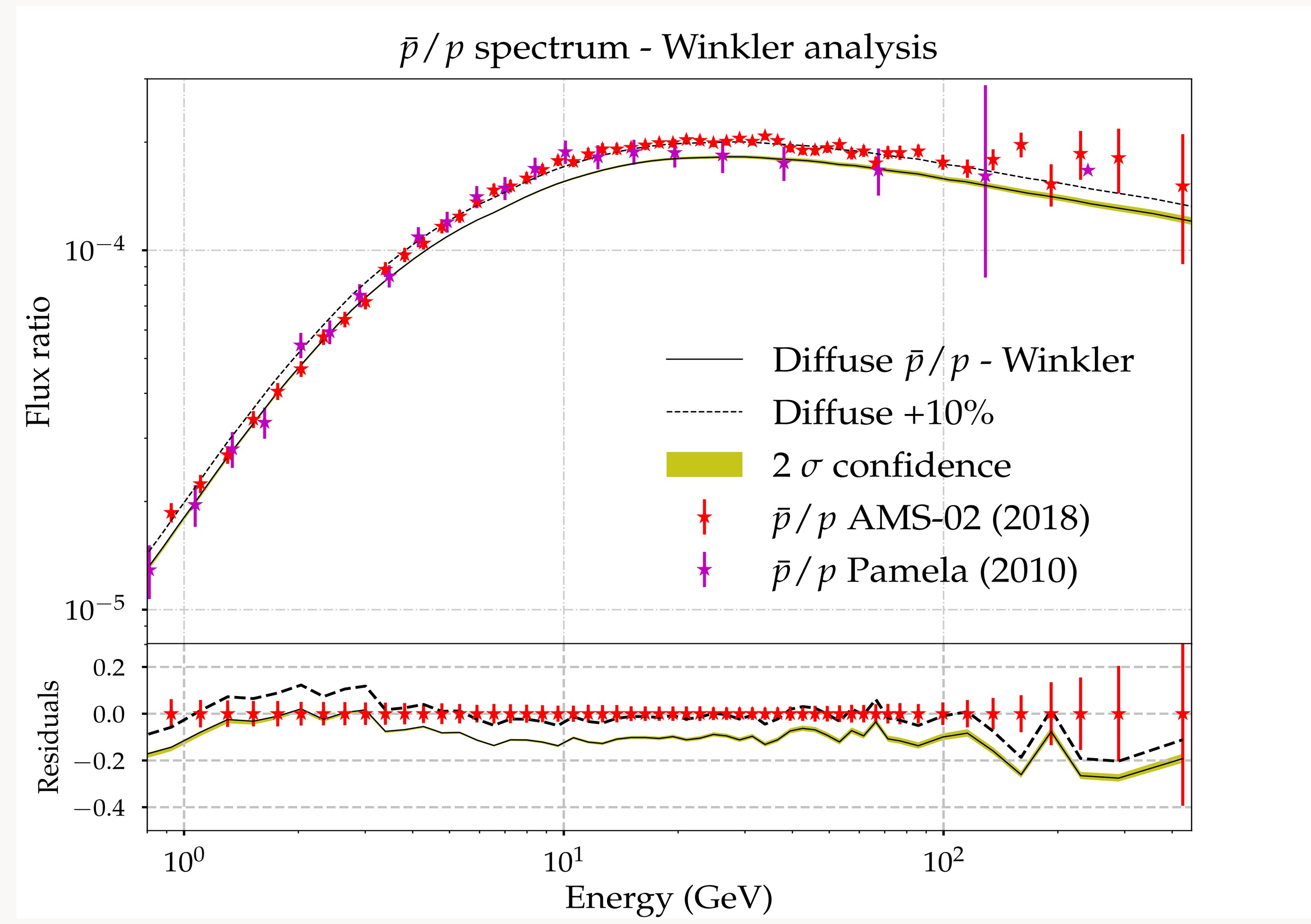
Propagation parameters				
H **[kpc]**	D_0 **(4GV) [10^{28} cm^2/s]**	V_A **[km/s]**	η	δ
6.07 ± 0.11	4.79± 0.1	0.28 ± 1.25	-1.57 ± 0.08	0.49 ± 0.01
[5.82, 6.27]	[4.59, 5.01]	[0., 2.8]	[-1.75, -1.39]	[0.46, 0.51]

Table: Best-fit values obtained in the combined analysis. The ± error given corresponds to the 1σ uncertainty. The 2σ uncertainty range is given for every parameter within square brackets.

Main result: Predicted $\bar{p}/p$ ratio.

The energy dependence predicted by our model is in very good agreement with that reported by AMS-02 above ~ 3 GeV, **without any need to invoke extra sources producing antiprotons**. We employ $\bar{p}$ production cross sections derived in Ref. [4] for this evaluation.

Residuals (model-data/data) are constant above ~ 3 GeV and at the level of 10%. In fact, this discrepancy does not resemble the typical bump-like structure that one would expect from possible extra sources of antiprotons.



The same prediction but scaled by 10% is shown as a dashed line. This **discrepancy can be plausibly explained by the uncertainties related to the cross sections of antiproton production**, estimated to be of the level of $\sim 20\%$ (see Ref. [5]).

Conclusions

We show that the energy dependence of the $\bar{p}/p$ spectrum is well reproduced assuming a pure secondary origin of antiprotons and that the discrepancy found is plausibly explained (within the 1σ uncertainties reported by AMS-02) by a rescaling of the cross sections of $\bar{p}$ production. Therefore, we conclude that taking into account all the sources of uncertainties in the evaluation of the secondary antiprotons produced from CR interactions allows us to explain the $\bar{p}/p$ spectrum without any need of extra sources, as dark matter annihilation in the Galaxy.

References

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