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Theoretical uncertainties in extracting cosmic ray diffusion parameters: the boron to carbon ratio

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PAMELA and, more recently, AMS-02, are ushering us into a new era of greatly reduced statistical uncertainties in experimental measurements of cosmic ray fluxes. In particular, new determinations of traditional diagnostic tools such as the boron to carbon ratio (B/C) are expected to significantly reduce errors on cosmic-ray diffusion parameters, with important implications for astroparticle physics, ranging from inferring primary source spectra to indirect dark matter searches.
It is timely to stress, however, that the conclusions inferred crucially depend on the framework in which the data are interpreted as well as from some nuclear input parameters. We aim at assessing the theoretical uncertainties affecting the outcome, with models as simple as possible while still retaining the key dependences.
We compare different semi-analytical, two-zone model descriptions of cosmic ray transport in the Galaxy: infinite slab/1D, cylindrical symmetry/2D with homogeneous sources, cylindrical symmetry/2D with inhomogeneous source distribution. We test for the effect of a primary source contamination in the boron flux by parametrically altering its flux, as well as for nuclear cross-section uncertainties. All hypotheses are compared via χ^2 minimization techniques to preliminary results from AMS-02.
We find that the major theoretical bias on the determination of the diffusion coefficient index δ (up to a factor two) is represented by the assumption that no injection of Boron takes place at the source. The next most important uncertainty is represented by cross-section uncertainties, which reach $\pm 20\%$ in δ. As a comparison, nuclear uncertainties are more important than the shift in the best-fit when introducing a convective wind of velocity >30 km/s, with respect to a pure diffusive baseline model. Perhaps surprisingly, homogeneous 1D vs. 2D performances are comparable in determining diffusion parameters. An inhomogeneous source distribution marginally alters the central value of the diffusion coefficient normalization (at the 10%, 1 σ level). However, the index of the diffusion coefficient δ is basically unaltered, as well as the goodness of fit.
Our study suggests that, differently for instance from leptonic case, realistic modeling of the geometry of the Galaxy and of the source distribution are of minor importance to correctly reproduce B/C data at high-energies hence, to a large extent, for the extraction of diffusion parameters.
The Ansatz on the lack of primary injection of Boron represents the most serious bias, and requires multi-messenger studies to be addressed. If that uncertainty could be lifted, nuclear uncertainties would still represent a serious concern, which degrade the systematic error on the inferred parameters to the 20\% level, or three times the estimated experimental sensitivity. In order to reduce this, a new nuclear cross-section measurement campaign is probably required.

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