AMS-02 Antiprotons Reloaded

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based on JCAP 09/2014 and arXiv:1506.04145

TAUP 2015
Torino

September 9 2015
Why Antiprotons?

- low fraction of antimatter in cosmic rays $\bar{p}/p \sim 10^{-4}$
- very sensitive probe for new physics
- complementary to gamma ray searches

example: dark matter pair-annihilation
no clear spectral features expected

precise prediction for the $\bar{p}$-background is indispensable
Secondary Antiprotons

- scattering of primary cosmic rays ($p, He$) on the interstellar matter

$$q^{sec}(T) \sim \int dT' \left( \frac{d\sigma}{dT} \right) \bar{p}_{prod} n_{A_{ISM}} \Phi_A \quad A = H, He, \ldots$$

- primary proton and helium fluxes

- clear indication of spectral breaks
Antiproton Cross Sections

- **new calculation of** $\bar{p}$ **production**

- **experimental data from NA49**

- **hyperon decay**

- **isospin enhanced** $\bar{n}$ **production**

  ![Graph showing isospin enhanced $\bar{n}$ production](image)

  - $\rho p$ Data
  - $p n$ Data
  - isospin factor 1
  - isospin factor 1.37

- **improved modeling of** proton-nucleus scattering

  ![Graph showing improved modeling of proton-nucleus scattering](image)
Propagation

- propagation: random walk through the galaxy

\[ \nabla (-K \nabla N_{\bar{p}} + \mathbf{V}_c \cdot \nabla N_{\bar{p}}) + \partial_E (b_{\text{loss}} N_{\bar{p}} - K_{EE} \partial_E N_{\bar{p}}) + \Gamma_{\text{ann}} N_{\bar{p}} = q_{\bar{p}} \]

- diffusion equation

- semi-analytic solution in two-zone diffusion model

- five transport parameters: \( K_0, \delta, L, V_c, V_a \) \( \iff \) B/C analysis
Antiproton Excess in AMS-02?

- preliminary data on the antiproton fraction in cosmic rays
  A. Kounine, Talk at the AMS Days at CERN (2015)

- dark matter interpretation

- background underestimated?
preliminary B/C data

A. Oliva, Talk at the AMS Days at CERN (2015)

- indicate that propagation parameters are outdated ⇒ reanalysis
Primary Fluxes

- B/C ratio used to determine propagation parameters
- B is pure secondary
- C, N, O, Ne, Mg, Si spallation contributes $\gtrsim 98\%$ to B flux
- data from ACE, HEAO, CREAM-II, PAMELA

Spallation Cross Sections

- $\sigma_{\text{spall}}$: straight-ahead approximation
- constant at $T \gtrsim 10$ GeV

Webber parameterization

- large uncertainties, no high-energy data
- introduce energy bias

needed: experimental data on spallation cross sections
B/C Analysis

- new AMS-02 data on B/C ratio
  A. Oliva, Talk at the AMS Days at CERN (2015)

- selected 500 configurations, trend towards smaller $\delta = 0.3 - 0.6$
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comparison of $\bar{p}$ background with new AMS-02 data
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- updated background consistent with data
**Antiproton Fraction**

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Comparison of $\bar{p}/p$ and $B/C$

![Graph showing comparison of $\bar{p}/p$ and $B/C$]
Comparison of $\bar{p}/p$ and B/C

$\bar{p}/p$ flatter by $\sim R^{0.25}$.
Comparison of $\bar{p}/p$ and $B/C$

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explained by injection
Remark on Propagation Uncertainties

\[ \sigma^{(12\text{C} \rightarrow \text{B})} \] [mb]

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\[ T [\text{GeV}] \]

\[ T [\text{GeV} / \text{n}] \]

\[ \frac{\bar{p}}{p} \text{ [pb]} \]

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Conclusion

- substantial progress in modeling antiproton production

- AMS-02 B/C data have strong impact on propagation parameters: higher slope of diffusion coefficient

- AMS-02 antiproton data are consistent with background