Antiprotons in cosmic rays

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Motivation

It is interesting to measure the antiproton galactic component in cosmic rays in order to study the mechanisms by which particles and antiparticles are generated and propagate in the Galaxy and to search for new sources.

This allows to investigate

• Existence of antimatter domains
• Properties of the interstellar medium
• Properties of the hypothetical dark matter particles
Antiparticle measurements by PAMELA

The sources of antiprotons in cosmic rays
• Secondary production
• Known astrophysical sources
• Decay or annihilation of dark matter particles or other exotic

Antiparticle measurements by AMS-02

Precise measurements are in agreement with PAMELA
Extension up to higher energies

PAMELA and AMS : Surprisingly hard CR pbar spectra!

From Gaëlle Giesen et al JCAP09(2015)023
Geometrical factor: $21.6 \text{ cm}^2 \text{ sr}$

**Magnetic spectrometer**
- Micro-strip silicon tracker + permanent magnet (5 sections)
- Measurement of rigidity $R$, determination of momentum $p$ ($R = pc/|Z|e$) and charge sign

**Scintillator system**
- Trigger formation, measurement of particle flight time through the spectrometer, suppression of background and albedo particles

**Time-of-flight system**

**Anticoincidence system**
- Scintillation screens
  - Exclusion of events outside the detector aperture and interacting in the container from analysis

**Electromagnetic calorimeter**
- W/Si position-sensitive ($16.3 \chi_0$, $0.6 \lambda_I$)
  - Separation of $e^+/p$, anti-$p/e^-$ and energy measurement of $e^-/e^+$

**Shower tail catcher scintillator and Neutron detector**
- Separation of electrons and hadrons at high energies
Updates in data processing

To improve the statistic and extend the energy range the next updates was done:

• updates of basic selection criteria;
• improvements of the simulation software;
• modern machine learning technique;
• improvements of spillover study;
• improvements of the efficiency study.

Processing all the scientific information (from 2006 to 2016).
Distribution by deviation in the magnetic field of selected negatively and positively charged particles with $|Z|=1$; good separation of the selected antiprotons (shaded histogram) and the "spillover" of protons is demonstrated.
Experimental data processing
As a result of the measurements, an antiproton/proton ratio was obtained in the energy range from 60 MeV to 500 GeV. This slide shows comparison with previous PAMELA result.

The statistic was increased 2 times. We must think about energy binning at \( E > 100 \) GeV.
Antiproton/proton fraction

And this one shows comparison with the latest AMS-02 result.
The main question: what about secondary production?
Results

- The ratio of antiproton and proton fluxes in the energy range from 0.08 to 600 GeV in primary cosmic radiation are obtained. These results are of interest for creating models of particle generation and propagation in the Galaxy, as well as for searching for and studying the nature of hypothetical dark matter particles.

- At present there is no clear answer to the question of the nature of antiprotons in cosmic rays. There are both articles indicating the existence of primary sources, and articles in which it is possible to explain the flux of antiprotons only by secondary origin.